Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

PROGRESS REPORT

May 2003 through May 2007

For the project

LONG-TERM ENVIRONMENTAL EFFECTS OF CONIFER REMOVAL TO ACHIEVE ASPEN RELEASE IN NEAR-STREAM AREAS WITHIN THE NORTHERN SIERRAS

Submitted to

Lassen National Forest

Submitted by

Principal Investigator
Kenneth W. Tate, Ph.D.
Rangeland Watershed Specialist
One Shields Ave
Mail Stop One
Department of Plant Sciences
University of California
Davis, CA 95616-8780
Voice: 530-754-8988
Fax: 530-752-4361
Email: kwtate@ucdavis.edu

Project Team
Bobette Jones, Melanie McFarland, Tom Rickman, Al Vasquez: USFS LNF
David Burton: Aspen Delineation Program
Shannon Cler: UC Davis
David Lile: UCCE Lassen County

1. Executive Summary

Following the adaptive management framework, several USFS Districts and Forests in California have begun to implement prescriptive conifer removal in conifer encroached aspen stands to conserve the stands, stimulate aspen regeneration, and recruit future cohorts of aspen to achieve full stand restoration. The purpose of the project detailed in this progress report is to provide the monitoring framework to assess the impacts of conifer removal from encroached riparian aspen stands on aspen recruitment, stream water quality, streamflow, stream canopy, stream temperature, aquatic macroinvertebrate community and aquatic habitat, and riparian soil quality. This project is a collaborative effort between USFS, UC Davis, and the interagency Aspen Delineation Program. Support has been provided as funding and in kind contributions from the USFS Region 5 Fish Habitat Relationships Program, the Lassen National Forest, and the Department of Plant Sciences at UC Davis. Over the past 5 years this collaborative venture has fostered the development of several complementary projects, greatly expanding the current scope of applied research focused on aspen conservation, restoration and management in the region.

Specific to the Lassen National Forest, three conifer removal projects have occurred during this project: 1) January 2004 Bogard Units project on 2 stands at Pine and Bogard Creeks; 2) August 2005 summer phase of the McKenzie project at Pine and Bogard Creeks; 3) September 2006 Brokeoff project at Bailey Creek. The purpose of the adaptive management study detailed in this report is to collect and report data to evaluate a suite of possible in-stream and near-stream impacts resulting from these projects. In this progress report we provide specific information about each of the projects, the monitoring design and analysis strategy, monitoring accomplished to date, as well as results available to date (May 2007). This report amends and updates all previous progress reports for this project, incorporating subsequent years of data collection.

Given the availability of both pre and post treatment data, we have focused the results section of this progress report on the evaluation of impacts of the January 2004 (Bogard Units project) and August 2005 (McKenzie project) on in-stream and soil parameters. We were able to find no consistent water related impacts from either project (i.e., water quality, water temperature, or macroinvertebrates). The January 2004 Bogard Units project did significantly reduce stream canopy cover and increase solar input to treatment reaches. There was no change in stream canopy of solar input associated with the August McKenzie project. There was a statistically significant increase in soil bulk density associated with the 0 to 3 inch soil depth following the January 2004 Bogard Units project, but we suspect this was an artifact of our sample design and inherent spatial variation in forest soil properties. There was no change in bulk density associated with the August 2005 McKenzie project based upon a cluster monitoring strategy designed to control for the impacts of spatial variation on repeatability of sample collection. Overall, results suggest that conifer removal projects implemented and monitored to date have had no negative impacts on stream habitat quality, stream hydrologic function, or water quality. Impacts on soil bulk density are minimal to non-existent. Data and analysis results supporting these conclusions are reported in Section 6 of this progress report.

2. Background

Trembling aspen (*Populus tremuloides* michx.) occurs in the montane zone of California's Sierra Nevada/Cascade range. In the West, aspen is considered a keystone species providing critical habitat to support plant and animal biodiversity in the region. Declines in the health and distribution of aspen stands across the region have been observed over the past century. That decline continues today. Much of this decline is attributable to conifer encroachment stimulated by the absence of natural fire regimes, as well as historic and current heavy browsing by domestic and native herbivores. The results of an aspen inventory conducted from 2000-2005 to assess the current status and risk of loss of 681 aspen stands (~95% of known stands) totaling 3,654 acres on the Eagle Lake Ranger District, Lassen National Forest documented that 77% of stands were at high risk of being lost. At least 37 known stands have expired with no living aspen present and no means of recruitment. If broad scale conservation and restoration action is not implemented immediately, a large majority of stands on that district may be lost. Conifer encroachment is the major risk factor associated with 96% of inventoried stands. These data reflect the condition of most aspen stands in the region, and provide a credible argument for the immediate release of

conifer encroached aspen stands followed by subsequent restoration actions such as controlling excessive grazing.

The advanced state and landscape scale of conifer encroachment induced aspen decline in the northern Sierra Nevada and southern Cascade indicates that: 1) restoration actions must occur sooner rather than later if the ecological services of aspen are to be preserved in the region (Jones et. al 2005); and 2) significant planning and implementation costs will be associated with restoration of degraded aspen stands. Logically and practically, prescriptive conifer removal has the potential to conserve a large number of conifer encroached aspen stands in the region which would otherwise transition to coniferous forest. Prescriptive conifer removal also has the potential to generate revenue to defray costs and fund additional restoration efforts such as protection from grazing. Jones at al. (2005) used prescriptive conifer removal in four extremely degraded aspen stands, releasing the stands to actively recruit and establish several new cohorts of aspen, thus conserving the stands. Additional research is required to quantify ecological service potentials (*e.g.*, herbaceous plant diversity, avian habitat structural complexity) and determining site constraints (*e.g.*, precipitation, elevation) so that achievable restoration targets can be set.

Broad scale implementation of prescriptive conifer removal in the region is an issue because a significant number of degraded stands are associated with riparian areas such as streams (Photos 1 and 2). Protection of riparian areas from silvicultural activities has justifiably strong legal and social support. However, conifer encroached riparian aspen stands that are not released will expire and overall riparian and landscape habitat complexity and biodiversity will continue to decline. Two causes as worthy as the protection of riparian areas and the conservation of aspen are surely not mutually exclusive, rather one could reasonably hypothesize that the restoration of riparian aspen stands would actually enhance overall riparian health. So, what are the negative impacts to riparian resources associated with aspen restoration initiated by prescriptive conifer removal? Which components of riparian resources are susceptible to negative impact: soils, water quality, aquatic habitat? If there are negative impacts, are they short or long-term? Will the ecological services that a restored aspen stand provides to the riparian area and the landscape out-weigh short or even long-term negative impacts to riparian resources? Answering these core questions is crucial to initiating an informed, broad-scale conservation and restoration of riparian effort for aspen stands in the region.

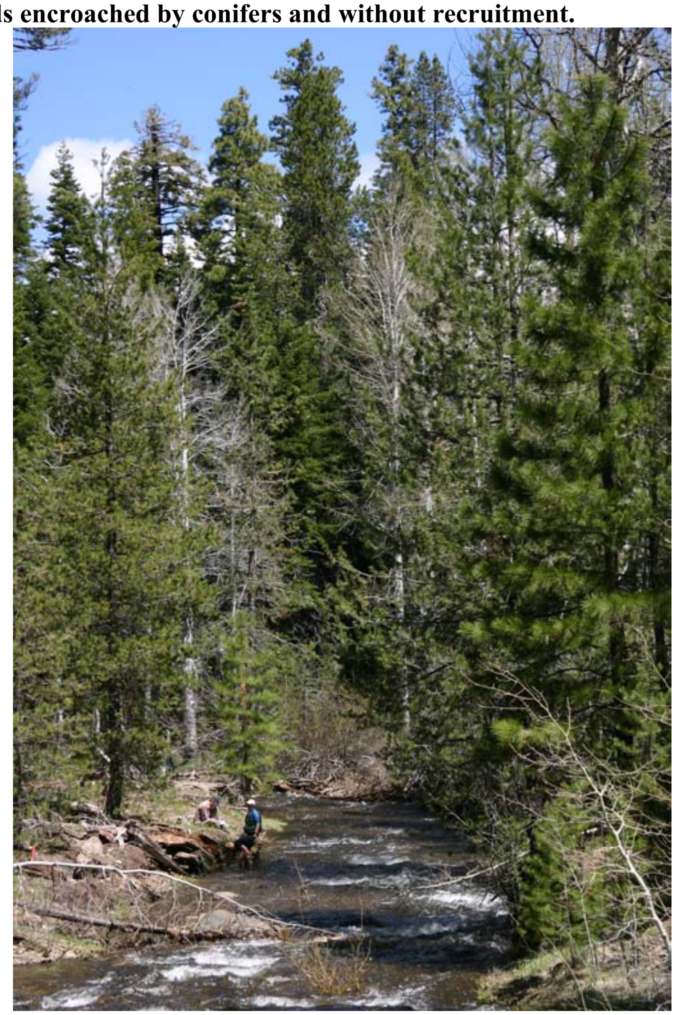
Adaptive management is an iterative process to identify and refine management to achieve defined natural resources objectives. It is founded upon active, not passive management. Conservation and restoration of aspen stands will require active, adaptive management. Adaptive management provides the manager, as well as other stakeholders, with the quantitative evidence that either: 1) progress is being made towards natural resources objectives and appropriate management practices are in place; or 2) progress towards natural resource objectives is not being made and management needs to be adapted. Central to this process is establishment of clear and measurable objectives, flexibility in management paradigms and implementation, and a data-based monitoring and evaluation framework to inform management of progress towards objectives. The management challenge we are facing is to design and implement prescriptive conifer removal strategies sufficient for conservation and restoration of encroached riparian aspen stands with minimal short-term and no long-term negative impacts on riparian resources. The overall goal of this project is to provide the monitoring and evaluation framework to assess impacts on riparian resources and progress towards aspen stand conservation and restoration.

Our specific monitoring objectives are to:

1) Evaluate the effectiveness of conifer removal as a means of successful aspen recruitment and stand establishment. **Completed** ✓

2) Conduct pre- and post- conifer removal monitoring of key stream attributes to evaluate effects on water resources. ***January 2004 Bogard project*** **Completed ✓** ***August 2005 McKenzie Project and September 2006 Brokeoff Project*** **On-Going**
3) Conduct pre- and post- conifer removal monitoring of soil attributes to evaluate effects on soil quality in riparian areas. ***January 2004 Bogard project*** **Completed ✓** ***August 2005 McKenzie Project and September 2006 Brokeoff Project*** **On-Going**
4) Extend and report the findings of this project to improve our ability to achieve Riparian Conservation Objectives as part of the Aquatic Management Strategy. **On-Going for all Projects**

Photo 1 and 2. Unhealthy Pine Creek riparian aspen stands encroached by conifers and without recruitment.



3. Treatment and Study Unit Definitions

A few definitions are provided here for clarity and consistency. The treatment is the removal of conifers from within degraded aspen stands located within stream riparian areas. The conifer removal strategy is designed to fully release aspen from conifer dominance, and may include a combination of commercial harvest, service contract and hand-thinning (Photo 3). The method and season in which conifers are removed will vary because each stand has different opportunities and constraints. Recent experience on the Lassen National Forest (LNF) indicates that the treatment should emphasize whole tree removal of conifers, of both pre-commercial and commercial size. Typically, all conifers less than 30” will be removed, except for conifers directly contributing to streambank stability or other site-specific benefits. Hand-felling of small diameter conifers may occur post-harvest. As a control, allowing evaluation of the

impacts of treatment, we selected degraded riparian aspen communities in the vicinity of each aspen stand scheduled for treatment implementation (e.g., Photo 1).

There are two study units in this project, as illustrated in Figure 1. For the purposes of examining aspen recruitment and soil quality parameters (Objective 1 and 3), the study unit is the area within each degraded aspen stand (treatment and control study stand). For the purposes of examining stream parameters (Objective 2), the study units are stream reaches (treatment and control study reach) adjacent to treatment and control aspen stands as defined by stream monitoring stations located above and below adjacent study stands. Discrete sampling stations, plots, and transects (experimental units) have been established within aspen stand and above and below stream reach study units to allow collection of appropriate pre- and post treatment data to achieve the project objectives. For instance, stream monitoring stations are situated to monitor changes in stream flow and water quality through study reaches. Soil sampling stations are situated to provide a representative sample of the whole study stand.

Photo 3. Encroached aspen stand liberated from conifer encroachment by an over-snow winter conifer removal project (Jan 2004) on Pine Creek, Eagle Lake National Forest. Photo taken May 2005.

4. Monitoring Design and Analysis Overview

The study design is based upon consistent, simultaneous monitoring before and after treatment application of treated and control study stands and adjacent stream study reaches (Figure 1). Statistical analysis is applied to this data to determine the magnitude and significance (statistical, not ecological) of response(s) of treated stands/reaches relative to control stands/reaches before v. after treatment implementation. For instance, stream temperature is collected above and below both control and treatment reaches both before and after conifer removal from the adjacent treatment stand. With this data set we can statistically test if say the treatment resulted in increased stream temperature gain through the treatment reach following

treatment. The pretreatment data from the control and treatment reaches serves as a benchmark, quantifying the increase in temperature through the treatment reach relative to the control reach prior to our treatment application. To determine if there is an increase in stream temperature through the treatment reach following treatment, we analyze all the data (before and after, above and below) to determine if there is a significant interaction between the factors location (above v. below conifer removal study site) and time (before v. after treatment). We are employing a linear mixed effects analysis to conduct this analysis to account for repeated measures introduced in the data set due to repeated sampling of the sample stations. A detailed, basic explanation of this analysis approach applied as a case study to stream temperature can be found at the following website, (Tate et al., 2005 http://californiaagriculture.ucop.edu/0503JAS/toc.html).

The basic form of this linear model is:

$y = b_0 + b_1*(\text{time}) + b_2*(\text{location}) + b_3*(\text{time X location})$

y = water temperature, soil organic matter level, etc.
time = before or after treatment
location = treatment or control, above or below

The terms b_0, b_1, b_2, and b_3 are coefficients estimated by a commercial statistical package (S-Plus 6.0) using a best fit approach known as restricted maximum likelihood. The significance of each coefficient ($b \neq 0$) is determined via a conditional t-test. For our purposes of determining treatment effect, we are mainly interested to determine if b_3 is significant. We use this model to test the hypothesis that the relative difference in y between treatment and control, or above and below, changed from before to after treatment by testing the significance of b_3 ($b_3 = 0$, $b_3 \neq 0$). If b_3 is significant ($b_3 \neq 0$), then the change in stream temperature above v. below the treatment stand changed significantly from before to after treatment implementation.

This approach does not assume above and below, or treatment and control, are originally identical (*i.e.*, replicates), but it does assume that the only major change during study period was in the treatment unit (conifer removal) and that the control was in a stable state throughout the time of comparison (before and after treatment). The same fundamental design and analysis approach described above for stream temperature is being applied for all variables of interest (e.g., stream canopy, water quality, soil bulk density).

5. Study Sites

At the outset of this project in early 2003, aspen stands and associated stream reaches selected for inclusion into the project: 1) were either scheduled or expected to be scheduled for implementation of a conifer removal treatment in the next 1 to 3 years; 2) had sufficiently similar stands and stream reaches in the vicinity to serve as controls; and 3) represented the range of precipitation regime found on LNF. Study stands and stream reaches at locations on Pine-Bogard Creeks, Butte Creek, and Brokeoff Meadow (Bailey Creek) were enrolled in the study (Figures 2a&b, 3, and 4). We selected sites near the confluence of Pine and Bogard Creeks on the Eagle Lake Ranger District due to treatment application scheduled for the January 2004 (Figure 2b "Bogard Units") and August 2005 and January 2006 (Figure 2b "Aspen_Enhance_Summer" and "Aspen_Enhance_Winter"). We selected stands and stream reaches on Butte Creek (at the boundary of ELRD and the Hat Creek Ranger District) and Brokeoff Meadow (HCRD) because both timber sales are expected to be scheduled for implementation in the within next few years. Butte Creek is a dry site, Pine-Bogard Creeks represents wet eastside conditions, and Brokeoff Meadow is located on the west-slope representing the highest precipitation regimes of LNF. To date (May

2007) the January 2004 Bogard Unit, the August 2005 McKenzie, and September 2006 Brokeoff projects have been implemented. The January 2006 McKenzie project has not been conducted on Butte Creek.

Figure 1. Illustration of study layout for a paired control and treatment aspen stand and associate stream study reach.

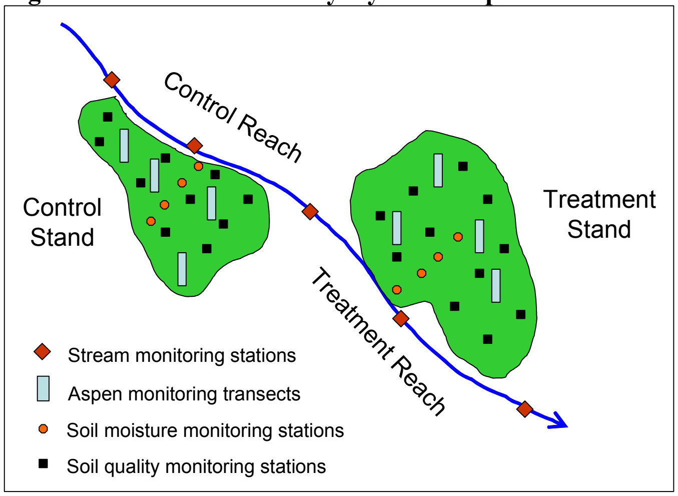


Figure 2a. Pine and Bogard Creek stream sampling locations and names.

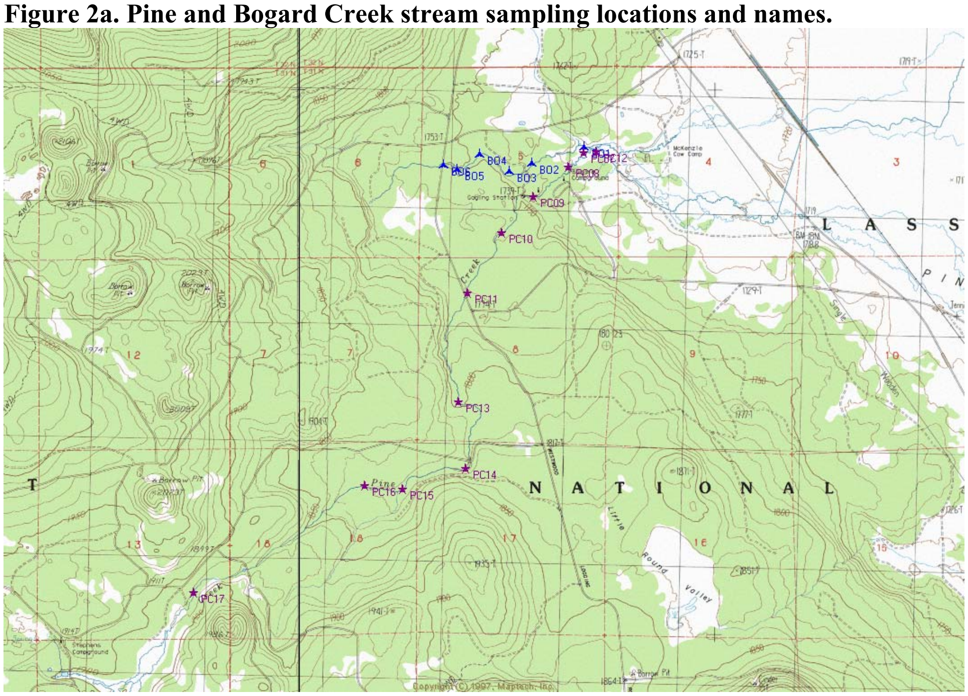


Figure 2b. Pine-Bogard Creek study location with monitoring stations and treatment areas marked.

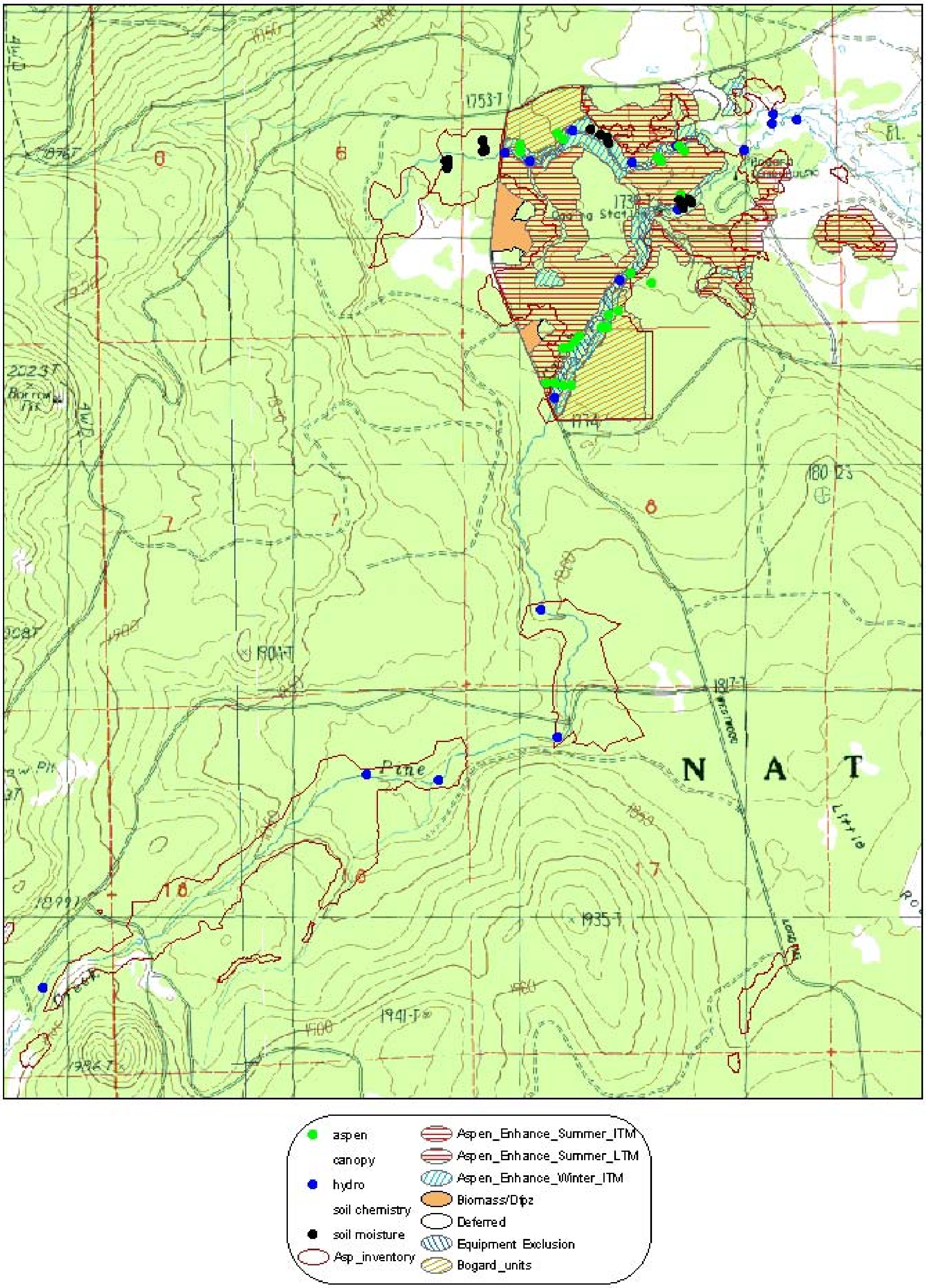


Figure 3. Butte Creek study location with stream monitoring stations marked.

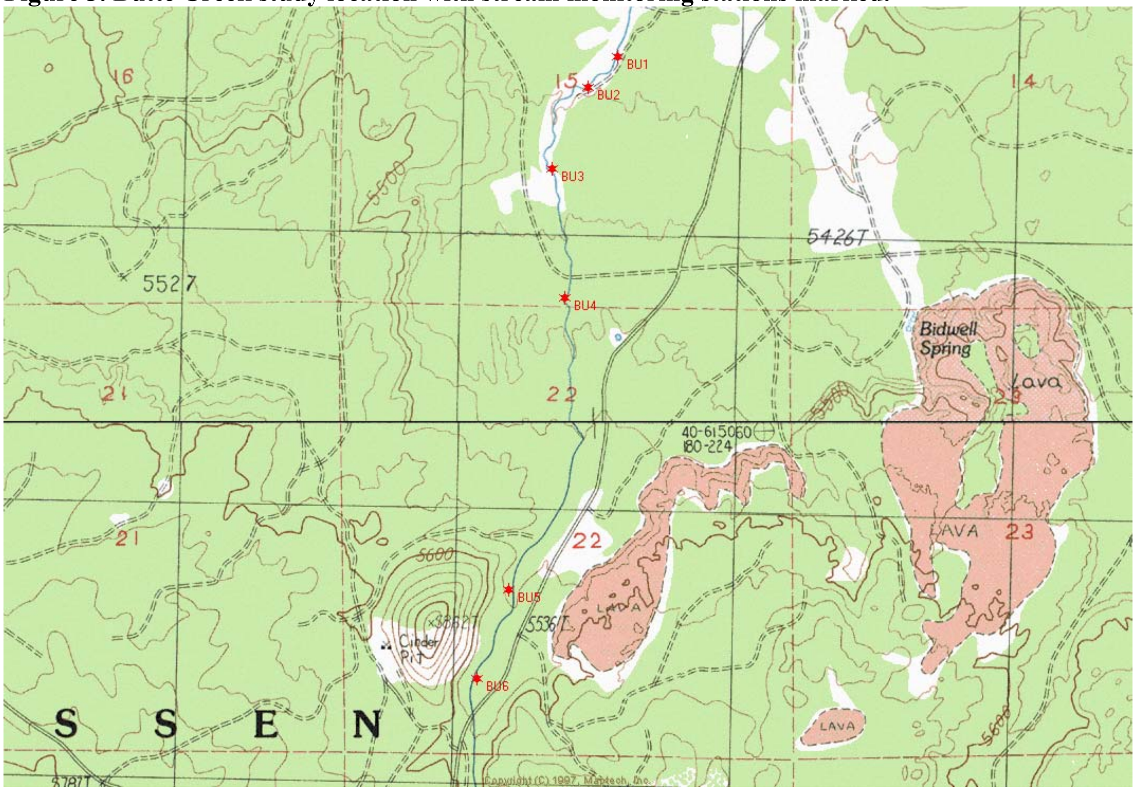
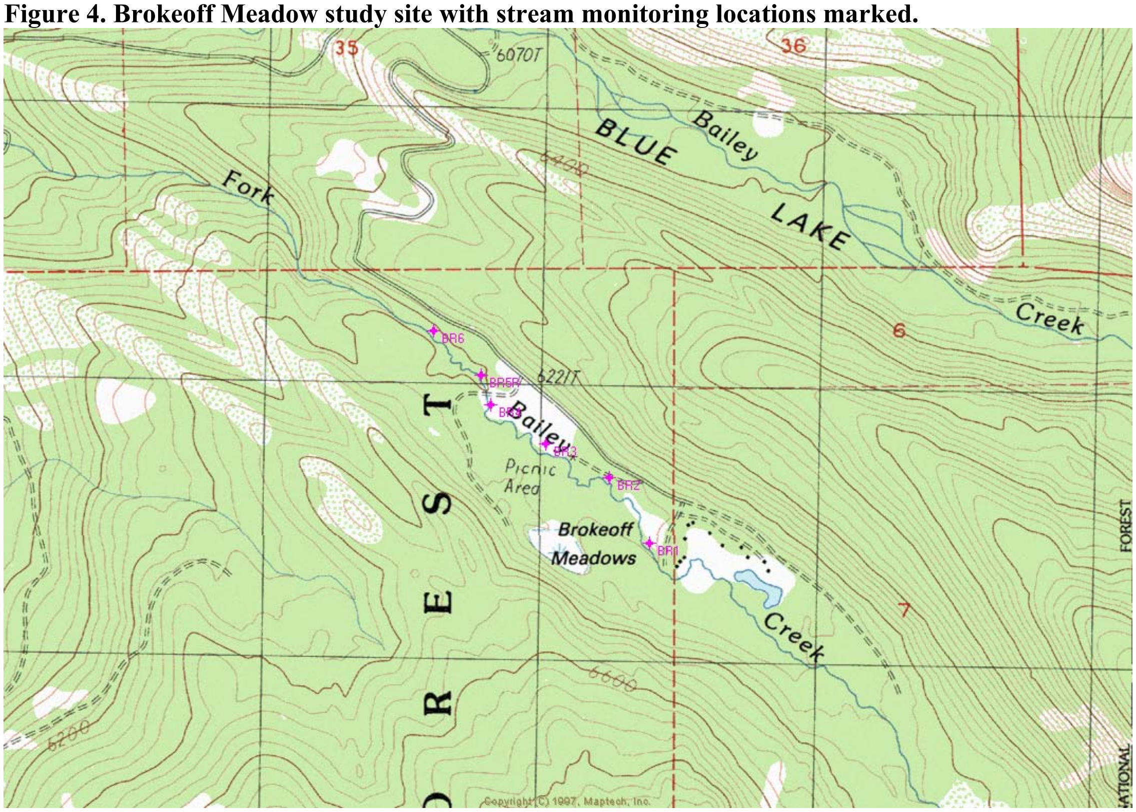


Figure 4. Brokeoff Meadow study site with stream monitoring locations marked.



6.0 Progress

6.1 Objective 1 Completed and Published

Objective 1 of this project has been accomplished. Within 3 to 4 years, the conifer removal activities conducted on LNF are conserving aspen stands and initiating restoration by stimulating significant recruitment of aspen in all four size classes. The data, analysis, and results supporting this conclusion are contained in a paper published in the journal *Restoration Ecology*.

Jones, B.E., T.H. Rickman, A. Vasquez, Y. Sado, and K.W. Tate. 2005. Removal of Competing Conifers to Regenerate Degraded Aspen Stands in the Sierra Nevada. *Restoration Ecology*. 13:373-379.

6.2 Annual Data Collection and Laboratory Analysis for Objectives 2 and 3

Annual collection of data over the 4 years (2003 through 2006) of this study has varied by study site, depending upon expected date of treatment implementation and date of achievement of 2 years of pre treatment data (our pre treatment data objective). Each year, data collection begins in May and continues through September. Tables 1 through 3 report parameters monitored for each study location, and the years of data existing for each location. All sample locations have been referenced with a global positioning system and permanently marked in the field to allow accurate repeated measurement and protection during treatment implementation. With the exception of macroinvertabrate analysis for 2005-2006, all laboratory analysis of water, soil, and macroinvertebrate samples collected 2003 through 2006 have been completed, entered and verified correct. In addition to field data collected by Eagle Lake Range District staff, Almanor Ranger District staff collected in-stream habitat and channel data following USFS Stream Condition Inventory protocol. We have completed collection of pre-treatment data from all sites for all parameters listed for each study site in Tables 1 through 3. We have complete pre and post treatment data from the January 2004 Bogard Units project and August 2005 McKenzie project along Pine and Bogard Creeks. We have complete pre treatment data from Bailey Creek (3 years) and Butte Creek (2 years).

Table 1. Pine – Bogard Creek sample stations and data collection.

Factor	Parameters Measured	Sample Stations	Data Frequency / Year	Years Collected
Water	Streamflow, water and air temperature, pH, dissolved oxygen, electrical conductivity, turbidity, total suspended solids, total N, total P, nitrate, ammonium, phosphate, potassium, sulfate.	17 monitoring stations which define 10 stream reaches	Temperature continuously collected, other parameters sampled every 2 weeks.	2003-2006
Aquatic Macroinvertabrates	Samples will be identified to family and various metrics of richness, diversity, and composition determined.	Samples collected at 8 water monitoring stations.	Samples collected once.	2003-2006
Stream Canopy Cover	Canopy density and percent of available solar radiation reaching the stream each month.	5 to 20 readings for each reach defined by 17 water monitoring stations	Samples collected once.	2003-2005
Soil Moisture McKenzie Project	Soil moisture at 6 and 18 inches depth.	16 monitoring stations (8 controls and 8 treatment).	Sampled every 2 weeks.	2003-2006
Soil Bulk Density Bogard Units	Soil samples have been collected at 0-3 and 3-6 inches depth for bulk density analysis	80 monitoring stations (40 controls and 40 treatment).	Sampled once.	2003-2005
Soil Quality Bogard Units	Soil samples have been collected at 0-3 and 3-6 inches depth for the following analysis: total N, nitrate, ammonium, phosphate, total C, organic C, and organic matter.	80 monitoring stations (40 controls and 40 treatment).	Sampled once.	2003
Soil Bulk Density McKenzie Units	Soil samples have been collected at 0-6 and 6-12 inches depth for bulk density analysis	3 monitoring stations with 25 samples per station (2 treatment stations, 1 control station).	Sampled once.	2004-2005
Aspen	Aspen density by 4 size classes and total.	10 transects (5 controls and 5 treatment fall/winter 2005)	Sampled once.	2003-2006
Stream Condition Inventory	LWD, substrate size distribution, channel gradient, entrenchment, W:D, residual pool depth, pools formed by wood, % pool tail surface fines, % shade, stream shore depth, bank angle, % undercut banks.	Jan 2004 treatment reach on Pine Creek	Sampled once.	2003-2004

Table 2. Butte Creek sample station establishment and data collection.

Factor	Parameters Measured	Sample Stations	Data Frequency / Year	Years Collected
Water	Streamflow, water and air temperature, pH, dissolved oxygen, electrical conductivity, turbidity, total suspended solids, total N, total P, nitrate, ammonium, phosphate, potassium, and sulfate.	6 monitoring stations which define 5 stream reaches (3 control, 2 treatment).	Temperature continuously collected, other parameters sampled every 2 weeks.	2003-2004
Aquatic Macroinvertabrates	Samples are being identified to family and various metrics of richness, diversity, and composition determined.	Samples were collected at 3 water monitoring stations.	Samples collected once.	2003-2004
Stream Canopy Cover	Canopy density and percent of available solar radiation reaching the stream each month.	5 readings for each reach defined by 17 water monitoring stations	Samples collected once.	2003
Soil Moisture	Soil moisture at 6 and 18 inches depth.	14 monitoring stations (5 controls, 5 treatment, and 4 already treated).	Sampled every 2 weeks.	2003-2006
Aspen	Aspen density by 4 size classes and total.	10 transects (5 controls and 5 treatment)	Sampled once.	2003-2004

Table 3. Brokeoff Meadow sample station establishment and data collection.

Factor	Parameters Measured	Sample Stations	Data Collection / Year	Years Collected
Water	Streamflow, water and air temperature, dissolved oxygen, electrical conductivity, turbidity, total suspended solids, total N, total P, nitrate, ammonium, phosphate, potassium, and sulfate.	6 monitoring stations which define 5 stream reaches (1 control, 4 treatment).	Temperature continuously collected, other parameters sampled every 2 weeks.	2003-2004, 2006
Aquatic Macroinvertabrates	Samples are being identified to family and various metrics of richness, diversity, and composition determined.	Samples were collected at 3 water monitoring stations.	Samples collected once.	2003-2004, 2006
Stream Canopy Cover	Canopy density and percent of available solar radiation reaching the stream each month.	5 to 20 readings for each reach defined by 17 water monitoring stations	Samples collected once.	2003, 2006
Soil Moisture	Soil moisture at 6 and 18 inches depth.	16 monitoring stations (8 controls and 8 treated).	Sampled every 2 weeks.	2003-2006
Soil Quality	Soil samples have been collected at 0-3 and 3-6 inches depth for the following analysis: total N, nitrate, ammonium, phosphate, total C, organic C, and organic matter.	80 monitoring stations (40 controls and 40 treatment).	Sampled once.	2003
Soil Bulk Density	Soil samples have been collected at 0-6 and 6-12 inches depth for bulk density analysis.	3 monitoring stations with 25 samples per station (2 treatment stations, 1 control station).	Sampled once.	2006
Aspen	Aspen density by 4 size classes and total.	10 transects (5 controls and 5 treatment)	Sampled once.	2003-2004, 2006
Stream Condition Inventory	LWD, substrate size distribution, channel gradient, entrenchment, W:D, residual pool depth, pools formed by wood, % pool tail surface fines, % shade, stream shore depth, bank angle, % undercut banks.	Treatment reach.	Sampled once.	2003

6.3 January 2004 Bogard Units Project along Pine and Bogard Creeks

Over snow conifer removal occurred during January 2004 between sites PC10 and PC11, and BO4 and BO6 on Pine and Bogard Creeks, respectively (Figure 2 b "Bogard Units", Photo 3 and 4). Total treatment area for this project was ~60 Acres, with harvest over snow to protect soil surface, whole tree removal to reduce slash, a track-laying harvester and rubber tire skidders were used >75 ft from stream, and hand felling with end-line removal of fallen trees was used within 75 ft of stream to protect riparian areas.

Combined with data collected in 2003 (before), data collected in 2004 (1 year after), 2005 (2 years after), and 2006 (3 years after) at sites PC10, PC11, BO4 and BO6 allow for complete analysis of before and after, above and below treatment differences for all stream related variables listed in Table 1. Data from other stream sample sites on Pine and Bogard provide insight into temporal (annual) and spatial (reach to reach) variation along these streams. Stream Condition Inventory data as well as stream canopy cover data were collected 2003 and 2004 along each treatment and control reach. Soil quality samples (Table 1) were collected before (June 2003) and 1 year after (June 2004). Also, soil bulk density samples were collected before (June 2003), 1 year after (June 2004) and 2 years after (June 2005) treatment along permanent transects within the 2 treatment stands and within 2 control stands. Data from all years has been entered, checked for accuracy, and statistical analysis conducted. Results of this analysis are reported below for key variables of concern.

Photo 4. Aspen stand north of sample stations BO4 and BO6 on Bogard Creek which received prescriptive conifer removal during Winter 2003/04. Left side illustrates post treatment, right side illustrates initial conifer encroachment level. Bogard Creek lies ~ 30m to the right of treatment boundary. Photo taken May 2005.

Stream Canopy Response
Stream canopy cover (%) was measured with a spherical densiometer and represents the amount of sky above a point on the stream channel which is blocked from view by vegetation (Photo 5a). It is a proxy for the amount of vegetative shade over a stream reach. In the arid, hot regions of northern California, vegetative canopy has been demonstrated to block solar radiation reaching the stream water surface and thus moderate water temperature (Tate et al. 2005, http://californiaagriculture.ucop.edu/0503JAS/toc.html). Stream temperature is a major habitat factor for cold water fish species in the region. Vegetative canopy also serves as an input of nutrients and organic matter to stream systems, influences in stream primary production, and macroinvertebrate assemblages (*e.g.*, shredders v. grazers). Percent of available solar radiation reaching the stream water surface was measured with a solar pathfinder (Photo 5b). This reading reflects the integrated effects of vegetative canopy, topographic shading, and stream channel aspect to block some portion (0 to 100%) of available solar radiation reaching a site at a given latitude for each month of the year. We concern ourselves with the months June through September which represent the warmest period in the region, when elevated stream water temperatures might be of concern.

There was a significant ($P<0.05$) reduction in vegetative canopy cover over the treatment reaches of both Pine and Bogard Creeks following conifer removal in adjacent aspen stands. Pine Creek canopy was reduced 10% and Bogard stream canopy was reduced 33%. Mean canopy cover before v. after treatment on Pine Creek was 70 and 60%, respectively. Mean canopy cover before v. after treatment on Bogard Creek was 82 and 49%, respectively. Figure 5 reports available solar radiation during the months June, July, August, and September received at the water surface for each stream before and after treatment. A significant increase in solar radiation reaching Bogard Creek was realized June through August as a result of the 33% reduction in canopy cover. The increase was not significant for September ($P>0.05$). The 10% reduction in canopy cover on Pine Creek resulted in somewhat greater solar radiation reaching the water surface in June. No significant difference existed for July through September before or after treatment along Pine Creek. The magnitude of error bars are a function of inherent variation in replicating solar radiation readings from year to year. To overcome this in future treatments we are significantly increasing the number of readings taken from each stream reach.

Variation in the magnitude of canopy cover reduction and increased solar radiation between streams is potentially due to several factors. First, Bogard Creek and it's riparian area is narrow (<3 m) compared to Pine Creek (>10 m) (Photo 6 and 7). Treatment guidelines excluded conifer removal from within the stream's riparian area, but allowed tree removal up to the defined edge of the riparian area. Given the narrow nature of Bogard Creek's riparian area, it is reasonable to expect that a large percentage of stream canopy cover is provided by near stream upland trees (BO4 to BO5 in particular). Whereas, it is our observation that the majority of stream canopy cover on Pine Creek (PC10 to PC11) is provided by trees rooted in the riparian area. Second, the aspect of conifer removal was north on Bogard Creek and south on Pine Creek. While this should not effect canopy reduction measurements, solar radiation measurements do integrate aspect. The potential influence of aspect of conifer removal to stream orientation (E-W, N-S) should receive some consideration in development of prescriptive conifer removal plans. We will soon have significantly more canopy and solar radiation data from additional reaches of Pine and Bogard scheduled for treatment Fall/Winter 2005, and will attempt a more complete evaluation of how aspect and riparian area width effect canopy cover and solar radiation following conifer removal.

Photo 5. Equipment used to measure stream canopy (a), solar radiation (b), and water temperature (c).

a) Spherical densiometer.

b) Solar pathfinder.

c) Optic StowAway.

Stream Temperature Response

Stream temperature was collected at each sampling station using Onset Optic StowAway temperature dataloggers (Photo 5c), set to record temperature every 0.5 hours. Temperature loggers were deployed ~May 15 and retrieved ~Sept 30 each year at each station. We examined several metrics of stream water temperature above and below treatment reaches before (2003) and after (2004, 2005, and 2006) conifer removal in adjacent aspen stands. Daily maximum and mean water temperatures, as well as 7-day running average daily maximum and mean water temperatures were calculated. For all metrics examined, and the difference in temperature between above and below stations was not different before v. after conifer removal in adjacent aspen stands. This result is based upon the lack of significance ($P>0.57$ in all cases) of an interaction between location (above v. below) and year (2003 v. 2004, 2005, and 2006). While temperatures below the treatment reach did increase from temperatures above the reach, the magnitude of increase was not significantly different between years. Figures 6 and 7 report 7-day running average daily maximum water temperatures above and below treatment reaches for both 2003-2006 on Pine and Bogard Creeks, respectively. It is important to note that maximum temperatures above and below treatment reaches on both streams remain well within optimal levels for all cold water fish species in the region (<67 ^{o}F).

This result indicates that although there was a reduction in stream canopy (10% on Pine, 32% on Bogard) which resulted in variable increases in solar radiation during the summer period, there was not a significant increase in stream temperature as a result. There are several possible reasons for this lack of response. First, there was minimal increase in solar radiation contributed to Pine Creek, particularly in July and August which are the warmest months in the region (Figure 5). Thus, it is not that surprising to see no stream temperature response on Pine Creek. However, Bogard Creek did sustain a relatively significant reduction in canopy cover (33%) and increase in solar radiation (Figure 5). Despite the reduction in canopy cover along the treatment reach of Bogard, there is still significant canopy cover (49%) following the treatment which may be providing sufficient shading to continue to moderate stream water temperature. It is also important to note that the Bogard Creek treatment reach is relatively short (<500 m). It is likely there is a relatively short residence time for water to pass through this reach. A short residence time would lessen the potential for water passing through the reach to be influenced by solar radiation arriving to the reach.

Photo 6 (left) and 7 (right). Photo 6 is Bogard Creek looking down stream from sampling station BO5 after conifer removal in aspen stand to the left side of picture. Photo 7 is Pine Creek looking up stream from sampling station PC10 after conifer removal in aspen stand to the left side of picture.

Figure 5. Available solar radiation received at water surface of treated reaches of Pine and Bogard Creek before (2003) and after (2004) conifer removal in adjacent aspen stands.

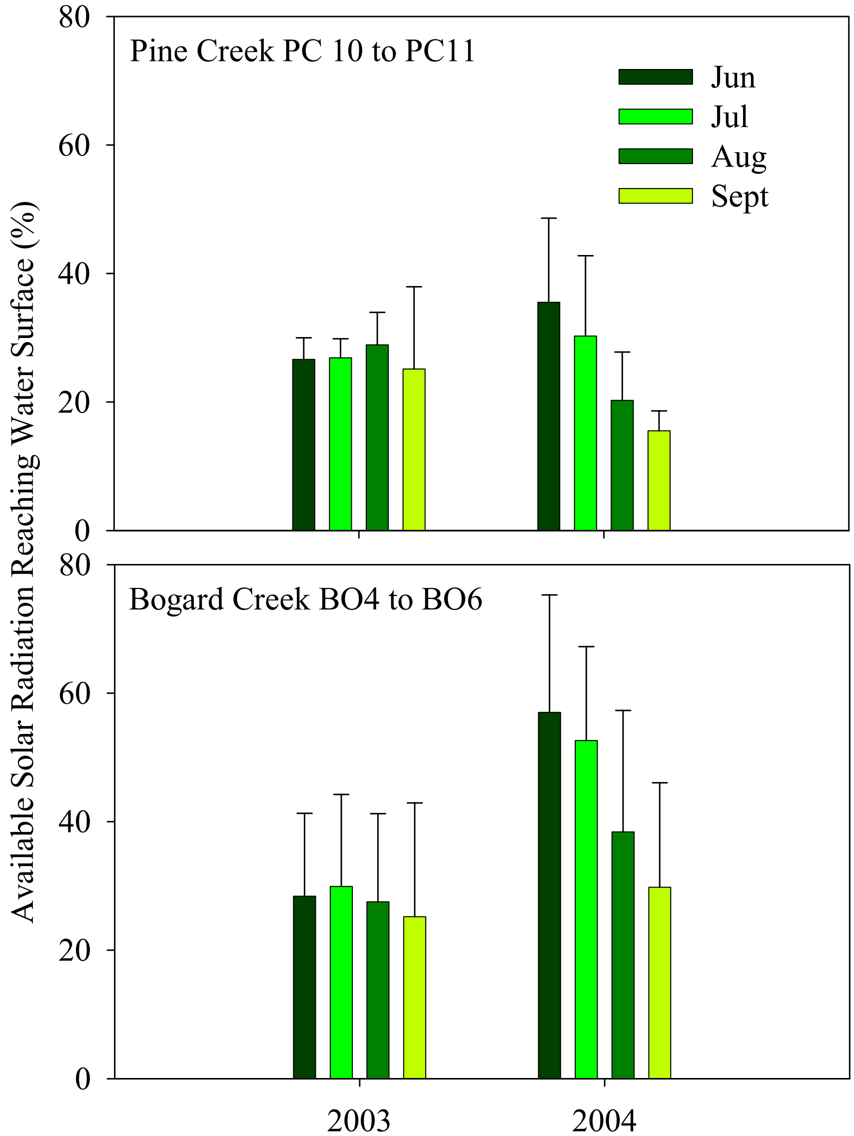


Figure 6. Seven day running daily maximum water temperature (F) on Pine Creek above (PC11) and below (PC10) the stream reach (PC10 to PC11) before (2003) and after (2004, 2005, 2006) conifer removal from an adjacent aspen stand.

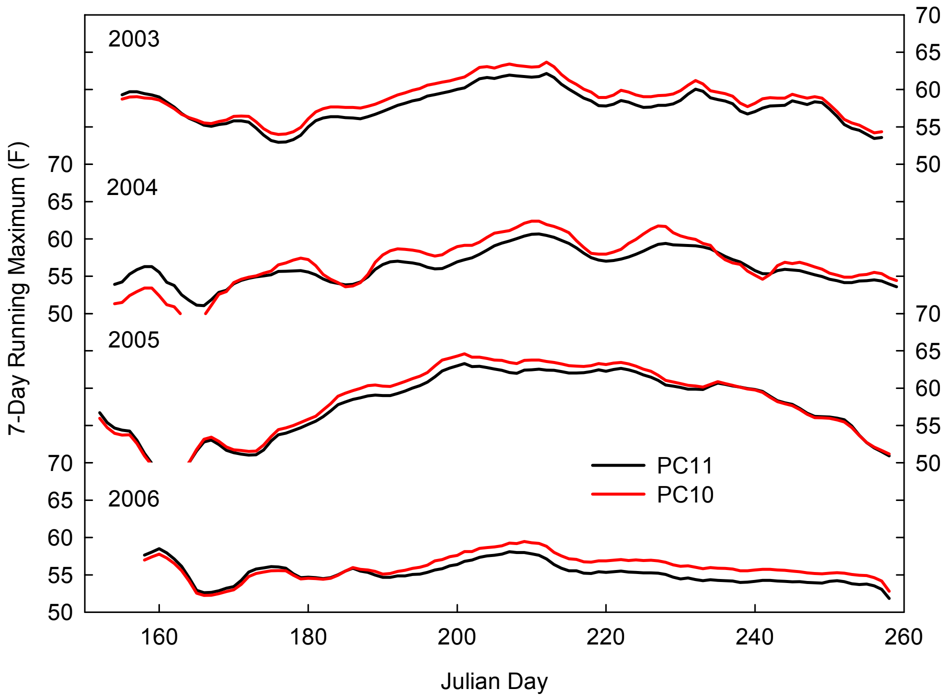
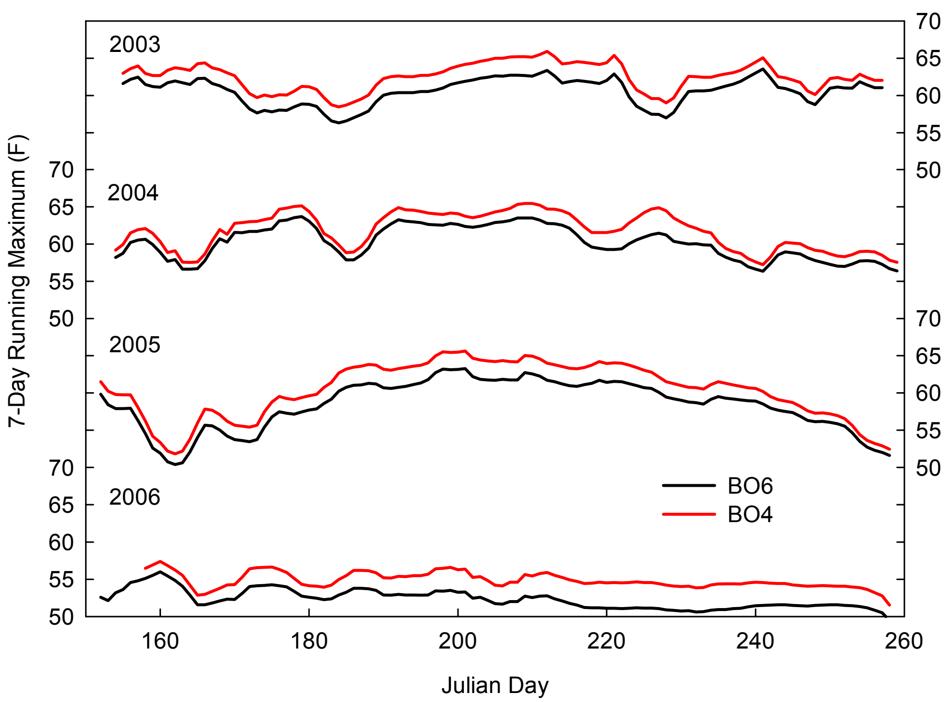


Figure 7. Seven day running daily maximum water temperature (F) on Bogard Creek above (BO6) and below (BO4) the stream reach (BO4 to BO6) before (2003) and after (2004, 2005, 2006) conifer removal from an adjacent aspen stand.



Stream Chemistry and Sediments

Stream water samples were grab sampled every 2 weeks from ~May 15 to ~September 30 above and below as well as before (2003) and after (2004, 2005, 2006) treatment on each stream (Photo 8a). Stream discharge (cfs) was measured at the same time as the grab sample was collected using the area velocity method (Photo 8b). Dissolved oxygen (mg/L) and electrical conductivity (dS/m) were determined at the time of grab sample collection and discharge measurement using standard field meters (Photo 8c). Grab samples were refrigerated (4 ^{o}C) and transported to UC Davis where they were analyzed for total suspended solids, electrical conductivity, pH, turbidity, and major anions and cations. Electrical conductivity (conductivity cell), pH (potentiometrically) and turbidity (turbidity meter) were measured on a non-filtered subsample. A separate aliquot of each sample was passed through a 0.45 µm membrane filter. Total suspended solids (g/L) were determined as change in mass of filter pre and post filtration on an analytical balance accurate to 0.001 g. The filtrate was analyzed for major cations (Na, Mg, K, Ca, & NH_4) and anions (Cl, SO_4, NO_3 & ortho-PO_4) by ion chromatography.

Tables 4 and 5 report discharge and water quality data collected from Pine and Bogard Creeks for 2003 and 2004 (year before and after treatment). Examination of the mean concentrations below treatment reaches for both streams in all 4 years (2003-2005) indicates exceptionally high water quality. This is also the case for all study sites enrolled in the project, regardless of status relative to treatment (Table 6). Figures 9 through 12 report mean sediment concentrations and turbidity for all sample sites along Pine and Bogard Creeks for 2003-2006. Overall, concentrations of nutrients and sediments are low, while average dissolved oxygen readings are well within the optimal range for cold water fish species in the region. As Table 6 reports nitrate, ammonium, and phosphate (primary nutrients of concern) are below our detection limit (0.01 ppm or mg/L) for the majority of samples collected from Pine and Bogard Creeks (data shown are downstream of treatment reach) for 2003 and 2004. Similar results have been found for these nutrient concentrations in samples collected at these sites during 2005 and 2006. These concentrations are several orders of magnitude below levels of concern for drinking water safety, as well as for eutrophication of downstream waterbodies.

To determine if there was a significant change in concentration due to treatment we tested the data to determine if an interaction existed between location (above v. below) and year (2003 v. 2004, 2005, 2006) for each constituent. The lack of significant change in discharge above v. below indicates that changes in concentration would not be due to dilution effects. Tables 4 and 5 report the results of this analysis for 2003 (year before) compared to 2004 (year 1 after). With the exception of total suspended solids and turbidity on Bogard and Pine Creek there was no significant change in constituent concentration through treatment reaches during any of the 3 years following removal of conifers. On Bogard Creek, there was a *decrease* of sediment and turbidity in 2004 below compared to above the treatment reach (Table 4), potentially due to filtering by a meadow reach below site BO6 (Photo 9). On Pine Creek there was an *increase* of sediment and turbidity in 2004 below compared to above the treatment reach (Table 5). Figures 9 and 10 report mean sediment concentrations and turbidity for all sites along Bogard Creek. Figures 8, 9 and 10 shows that sediment concentration and turbidity at BO4 (below) did significantly decrease compared to BO6 (above) in 2004 relative to 2003 (before treatment) ($P<0.05$). While apparent, BO4 sediment concentration was not significantly lower than BO6 in 2005 and 2005 (Figure 9, $P>0.36$). Turbidity was not different between the sites in 2005 or 2006. (Figure 10, $P>0.53$). Figures 11 and 12 report mean sediment concentration and turbidity for all sites along Pine Creek. Figure 11 shows that sediment concentration at PC10 (below) did significantly increase compared to PC11 (above) in 2004 and 2005 relative to 2003 (before treatment) ($P<0.05$). There was no significant difference between sites in 2006 ($P=0.74$). Turbidity did remain slightly elevated at PC10 compared to PC11 during all 3 years post treatment ($P<0.05$).

Although *statistically* significant, the changes which occurred in sediment concentration and turbidity between the above sites (BO6 and P11) and the below sites (BO4 and P10) before and after treatment along these reaches must be interpreted with caution. First, one could infer positive treatment effect from the Bogard results, or negative effect from the Pine Creek results. It is important to consider the overall patterns and annual variation along both creeks during this time period, as well as the overall magnitude of sediment concentrations and turbidity across years. For example, Figure 11 illustrates that several stream reaches above the treatment reach (PC11 to PC10) experienced similar fluctuations from 2003 to 2006 as those realized through the treatment reach (e.g., PC16 to PC15, and PC14 to PC13). The purpose of including these upstream (control) reaches in the study was to provide perspective for evaluation of annual changes and variation realized in treatment reaches. The occurrence of similar annual variation and patterns in these control reaches indicates that variation in treatment reaches between 2003 and 2004 (i.e., increase for Pine Creek, decrease for Bogard Creek) was within the inherent variation of these streams in the absence of treatment. Streams naturally gain and lose sediment along their length, and this gain-loss will vary from year to year and from reach to reach. A functioning stream will achieve a balance between sediment gain and loss.

Figures 9 and 11 illustrate that 2004 had the highest sediment concentrations of the study period for all sites regardless of location relative to treatment (above or below). During 2005 and 2006, sediment and turbidity levels for almost all sites, including those below treatments, were below levels realized in 2003 (pre treatment). There is no quantitative water quality standard for sediment concentration. The turbidity standard for water *generated* by a municipal drinking water treatment plant is 2 ntu. It is important to note that turbidity levels for all sites along both creeks were below this standard during 2003, 2005, and 2006. During 2004 (year 1 post treatment) this standard was only exceeded by sites *above* the treatment reach on Pine Creek, and by 1 site above and 1 below on Bogard Creek. Taken collectively, the variation in response along treated reaches on Bogard v. Pine Creek, the inherent variation exhibited through upstream control reaches on Pine Creek, the attainment of drinking water turbidity standards at almost all sites for all years, and the lack of significant change in percent fine sediments in pool tails and pool depth (Table 7) these results indicate that no real changes in sediment dynamics occurred within either stream as a result of this treatment.

Table 4. Mean stream discharge and water quality for Bogard Creek below the treatment reach (BO4), as well as the difference between above (BO6) and below (BO4) the treatment reach before (2003) and after (2004) conifer removal in an adjacent aspen stand.

Parameter	2003 Below	2004 Below	2003 Change	2004 Change
Discharge (cfs)	0.86	0.87	-0.02	-0.16 [n.s]
Total Suspended Solids (mg/L)	7.81	16.29	0.87	-8.71*
Turbidity (ntu)	1.09	3.54	0.33	-2.28*
Nitrate-N (mg/L)	<0.01	<0.01	--	--
Ammonium-N (mg/L)	<0.01	<0.01	--	--
Ortho-Phosphate (mg/L)	0.10	0.04	-0.01	-0.03 [n.s]
Potassium (mg/L)	2.25	2.00	0.09	-0.09 [n.s]
Sulfate (mg/L)	0.08	0.53	0.01	0.01 [n.s]
pH	7.52	7.66	0.04	0.05 [n.s]
Electrical Conductivity (ds/m)	90.61	97.18	-0.85	1.27 [n.s]
Dissolved Oxygen (mg/L)	6.95	6.98	-0.41	0.61 [n.s]

[*] Significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), P<0.05.
[n.s.] No significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), P>0.05.

Table 5. Mean stream discharge and water quality for Pine Creek below the treatment reach (PC10), as well as the difference between above (PC11) and below (PC10) the treatment reach before (2003) and after (2004) conifer removal in an adjacent aspen stand.

Parameter	2003 Below	2004 Below	2003 Change	2004 Change
Discharge (cfs)	13.94	4.53	-0.73	-0.01 [n.s]
Total Suspended Solids (mg/L)	5.05	8.47	0.81	5.06*
Turbidity (ntu)	0.37	0.93	-0.05	0.36*
Nitrate-N (mg/L)	<0.01	<0.01	--	--
Ammonium-N (mg/L)	<0.01	<0.01	--	--
Ortho-Phosphate (mg/L)	0.02	0.03	0.01	0.01 [n.s]
Potassium (mg/L)	1.38	1.31	-0.01	0.04 [n.s]
Sulfate (mg/L)	0.04	0.27	0.01	0.01 [n.s]
pH	7.49	7.59	0.08	-0.03 [n.s]
Electrical Conductivity (ds/m)	58.23	65.89	0.51	-0.29 [n.s]
Dissolved Oxygen (mg/L)	6.92	6.39	-0.39	0.62 [n.s]

[*] Significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), P<0.05.

[n.s.] No significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), P>0.05.

Table 6. Mean discharge, water quality, and aquatic habitat values for all four streams enrolled in study. Data represent the lowest sample station on each stream and were collected May – September 2004.

	Pine		Bogard		Butte		Bailey	
Parameter	Mean[1]	%<dl[2]	Mean	%<dl	Mean	%<dl	Mean	%<dl
Discharge (cfs)	6.6	0	0.8	0	11.2	0	14.2	0
Daily Max. Temp. (F)	56.7	0	58.7	0	65	0	52.6	0
Daily Mean Temp. (F)	51.9	0	50.0	0	58.1	0	47.4	0
D.O. (mg/L)	8.1	0	9.9	0	7.4	0	7.9	0
TSS (mg/L)	5.2	0	8.9	0	5.1	0	5.3	0
Turb. (ntu)	0.9	0	1.7	0	0.7	0	0.9	0
pH	7.5	0	7.6	0	7.5	0	7.1	0
E.C. (dS/m)	65	0	95	0	52	0	41	0
NO_3-N (mg/L)	0.01	76	0.01	75	0.01	57	0.01	51
PO_4-P (mg/L)	0.03	79	0.08	18	<0.01	89	<0.01	82
SO_4-S (mg/L)	0.16	13	0.39	0	0.42	0	11.53	0
NH_4-N (mg/L)	0.3	98	<0.01	100	0.21	88	0.11	78
K (mg/L)	1.43	0	2.04	0	1.13	0	0.73	0

[1] Mean of all water samples above detection limit (0.01 mg/L for NO_3-N, PO_4-S, SO_4-S, and NH_4-N).
[2] Percent water samples collected which were below the detection limit.

Photo 8. Water quality and stream discharge data collection.

a) Grab sample collection.

b) Streamflow measurement.

c) Dissolved oxygen measurement.

Photo 9. Bogard Creek showing road and culvert above sample station BO6 (a) and small meadow reach between BO5 and BO6 (b).

a) Road and culvert 10 m above BO6.

b) Looking upstream from BO5.

Figure 8. Stream discharge and total suspended solid concentrations above the treated reach (BO6) of Bogard Creek before (2003) and after (2004) removal of conifers in an adjacent, down-stream aspen stand.

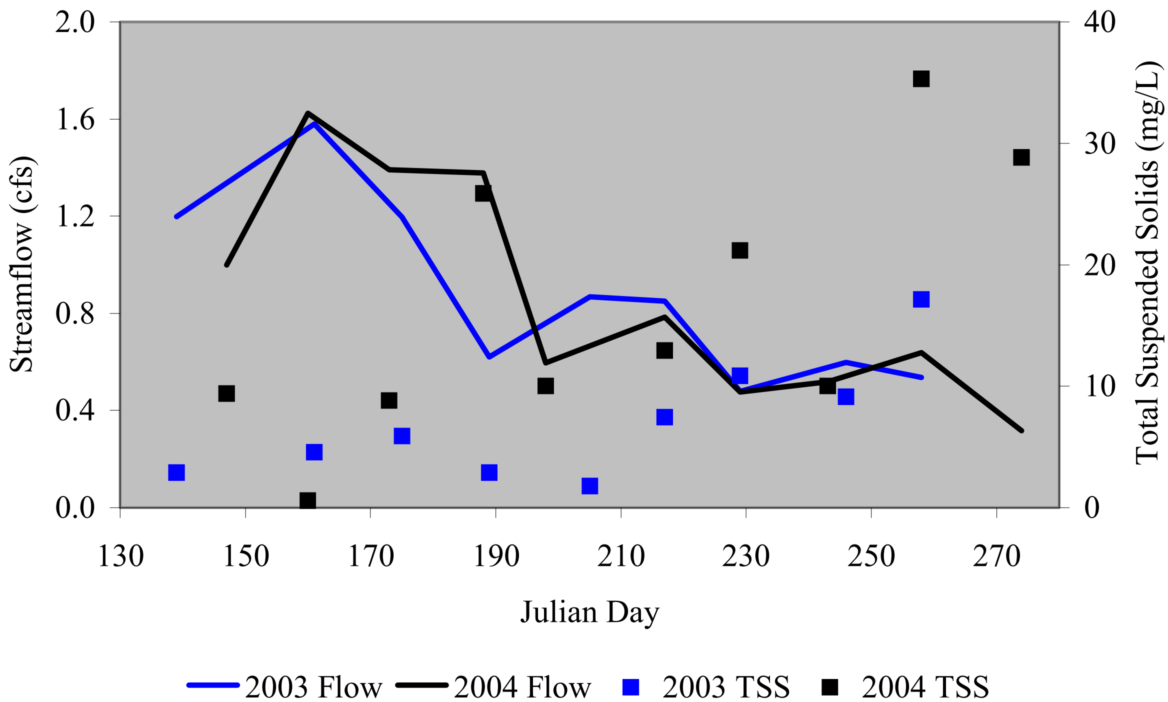


Figure 9. Suspended sediment concentrations for Bogard Creek sample sites 2003-2004.

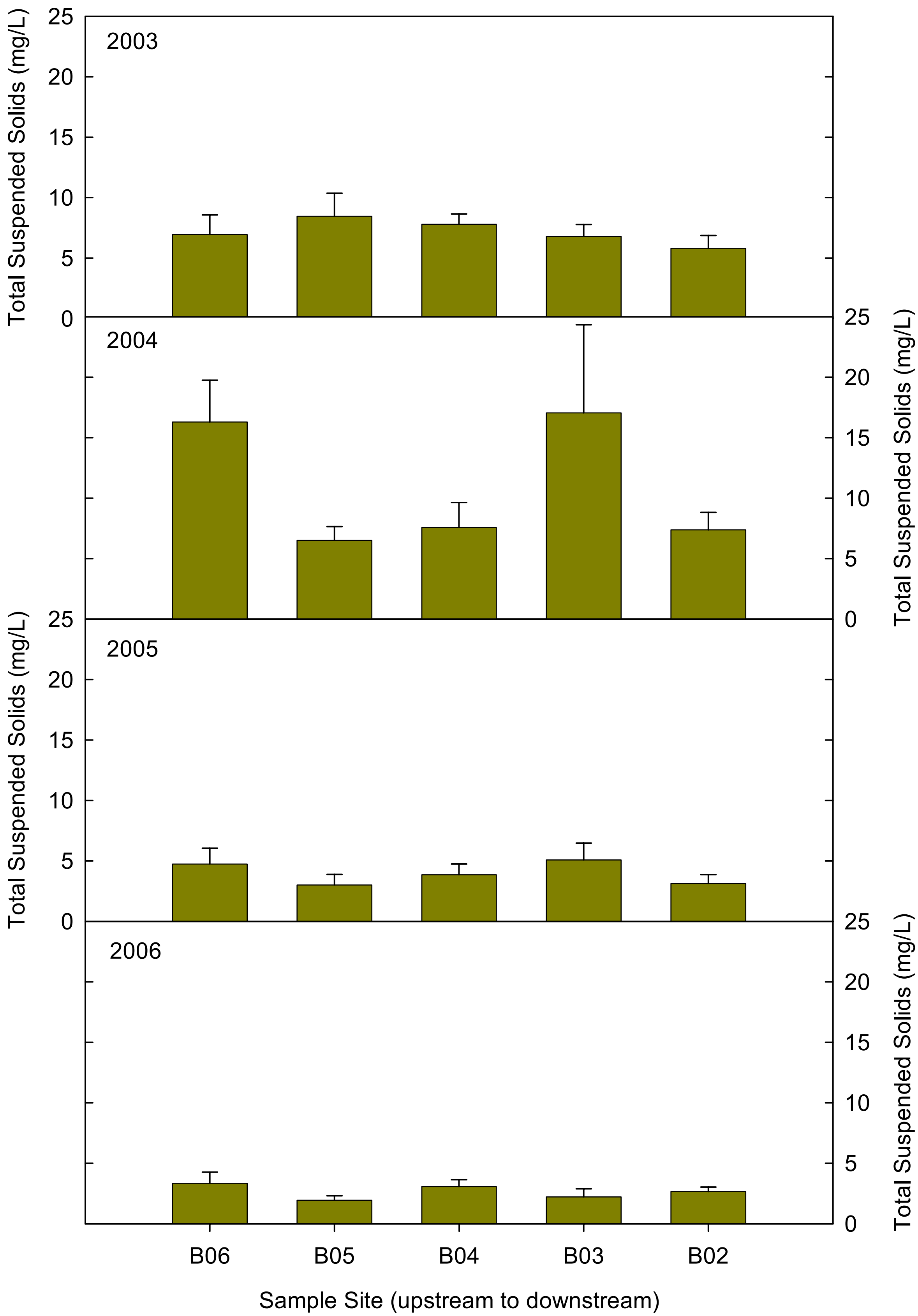


Figure 10. Turbidity levels for Bogard Creek sample sites 2003-2004.

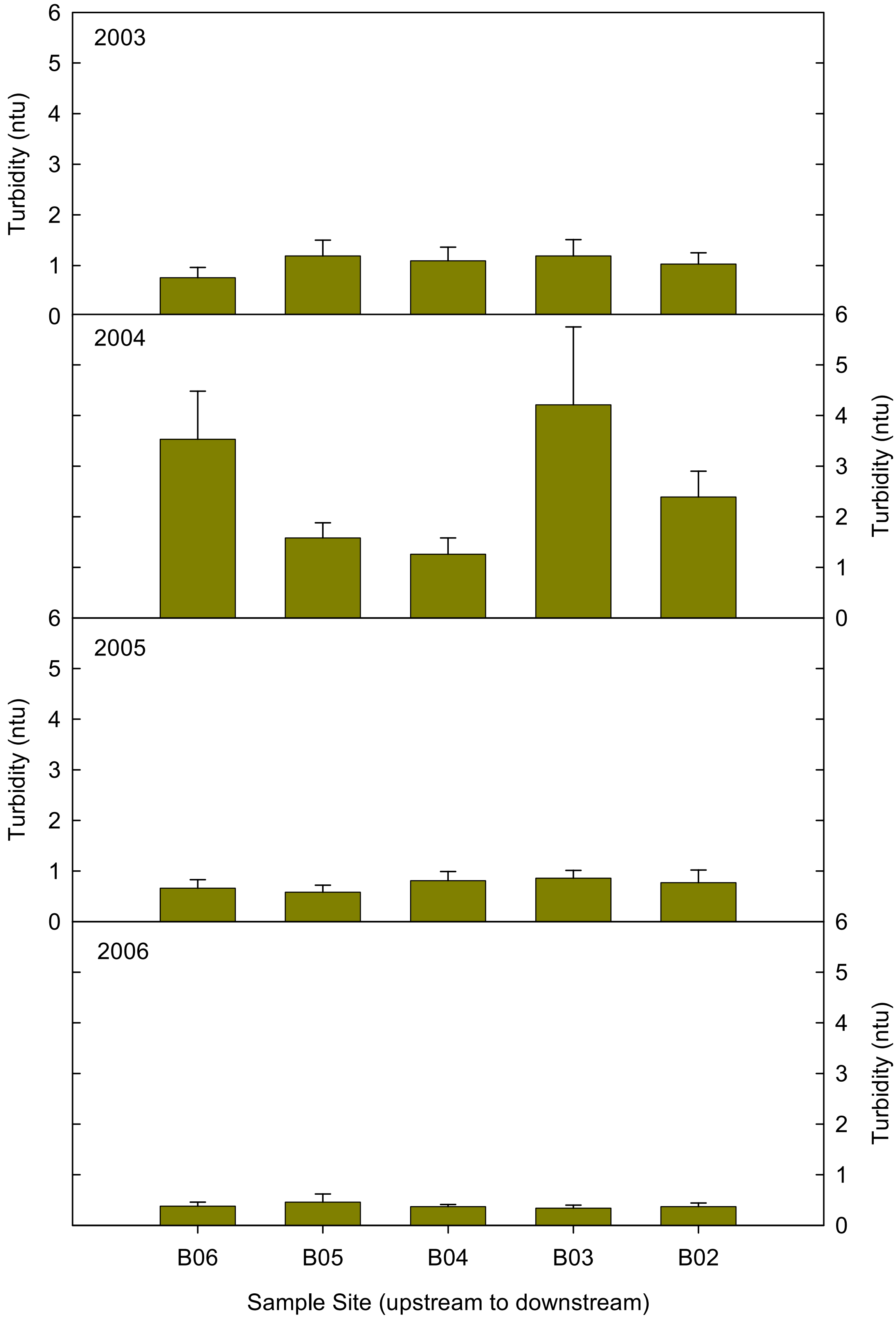


Figure 11. Suspended sediment concentrations for Pine Creek sample sites 2003-2004.

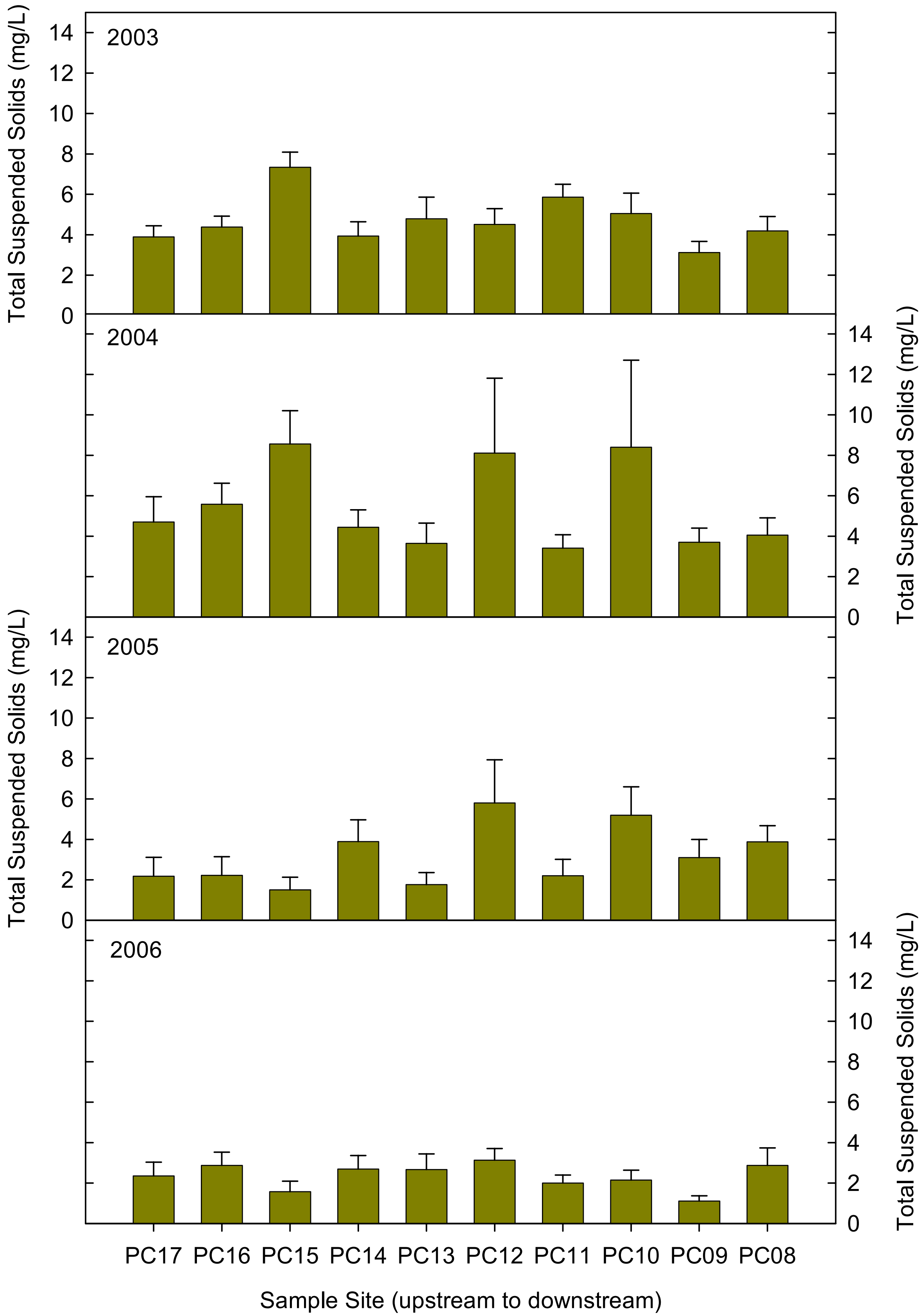


Figure 12. Turbidity levels for Pine Creek sample sites 2003-2004.

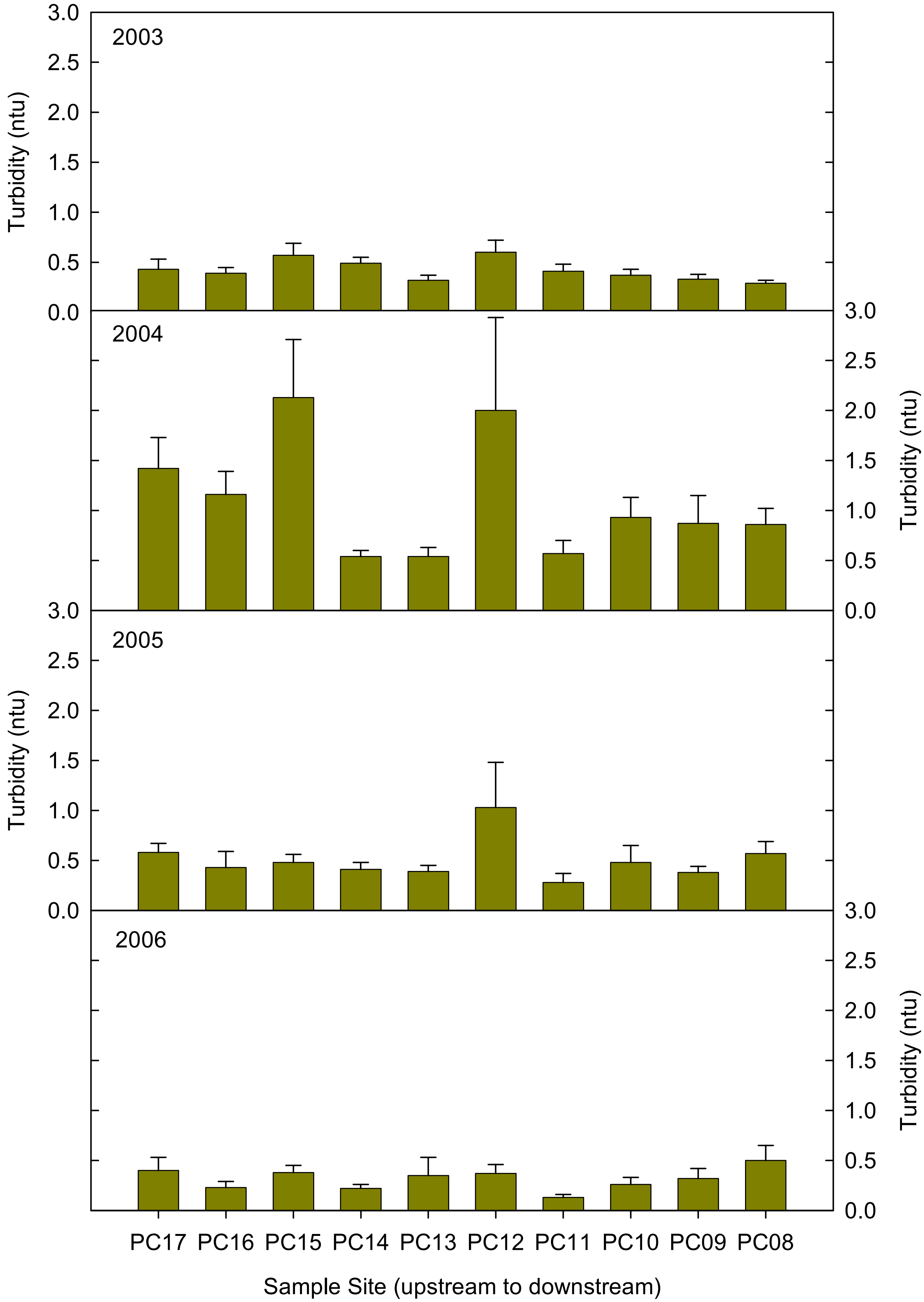


Table 7. Stream condition inventory data collected 2003 (before) and 2004 (after) on treatment reach of Pine Creek.

Pine Creek Aspen Site (below rd 32N22)	aggs	no in aggs	< 2mm	D_{50}	Entrenchment	W:D Ratio (Monuments)	W:D Ratio	Residual Pool Depth	Wood formed Pools	% Pool Tail Surf Fines	% Stable Banks	% Shade	Stream Shore Depth (m)	Bank Angle (degrees)	% Undercut Banks
Lower Pine 2004															
Mean				29.90	1.56	21.70	17.40	0.41		7.00		60.70	no data	144.00	16
Range					1.2-1.7	20.8-22.8	9.7-24	.28-1.17		0-54		34-100		45-176	
n			300		6	3	6	22		60	100	50		100	100
Count or %	10.00	125.00	1.70						5		65				
Lower Pine 2003															
Mean					2.1	19.7	no data	0.43		8.3	39	70	0.14	146	17
Range					1.7-2.8	19.2-24.2		.22-.1.16		0-60		24-95	0-0.45	55-175	
n			329.00		3	3		23		63	100	50		100	100
Count or %	11.00	74.00	15.50	15.90					5		39	0	17		

Stream Condition Inventory

Stream Condition Inventory was conducted 2003 and 2004 on the treated reach of Pine Creek. The channel is moderate gradient (about 2 percent), and therefore probably moderately sensitive to change. Comparison of data collected in 2003 and 2004 is summarized in Table 7 indicate no increase in any measure of sediment in the channel (particle count, pool tail fines, residual pool depth) or change in channel morphology (W:D ratio, wood formed pools. In fact, surface fines and particle count percentage less than 2% size class decreased slightly, but within error of the measurements.

Stream Macroinvertabrate Response

Stream macroinvertabrate collections were made at three locations along Pine and Bogard Creeks 2003 and 2004, and taxonomically analyzed to genus and species where possible. Similar collections were made in 2005 and 2006, and these samples are currently being taxonomically analyzed. Samples were collected with D-ring kick net (500 micron mesh) from a sample area of 1 ft^2 for a sample time of 3 minutes per sample, following standard CA Dept. Fish and Game protocols. At each sample station (e.g., BO1, PC13), 3 transects were sampled along a 100 m reach encompassing the sample location. Three collections were made along each transect (left bank, stream center, right bank) and composited as 1 sample for analysis. Transects were established across riffles. Taxonomic analysis was conducted at the BLM BugLab on the campus of Utah State University.

Tables 8 and 9 report key stream macroinvertabrate metrics calculated from collections made at sample locations on Bogard and Pine Creeks in 2003 and 2004, respectively. Collectively, these data indicate high water quality and in-stream habitat conditions. For all locations, the percent of the macroinvertebrate community tolerant of pollution (% Tolerant) is essentially zero (Tables 8 and 9). As with sediment concentration, there are no clear patterns relative to location and timing of treatment. Variation that exists from site to site and year to year is likely reflecting inherent site habitat quality and annual variation due to timing of insect hatch and community development. Percent (%) EPT is the percent of the collection composed of mayflies, stoneflies and caddisflies, and would be expected to decrease as pollution (e.g. sedimentation, increased temperature) increased. Patterns (or lack of) of % EPT for both Bogard and Pine Creeks do not indicate significant change in water or habitat quality before v. after, below v. above the treatment. Data presented here indicate no significant change in macroinvertabrate community attributable to treatment on Pine and Bogard Creeks.

Table 8. Macroinvertabrate metrics for Bogard Creek sample stations collected June-July 2003 and 2004.

	BO1		BO4		BO6	
Metric	2003	2004	2003	2004	2003	2004
No. Families	15.0	13.0	17.0	16.5	11.5	20.0
Diversity	2.47	2.26	2.83	2.09	2.00	2.22
% Tolerant	0.0	0.0	0.0	0.0	0.0	0.0
% Intolerant	28.0	44.7	24.3	12.8	28.9	11.0
% Dominant Taxa	20.1	21.2	36.9	45.4	38.8	42.5
% EPT	46.4	60.8	40.7	39.6	35.4	35.9
% Diptera	45.2	36.3	52.2	35.9	54.9	20.2
% Chironomidae	23.8	24.0	10.3	49.2	16.0	16.2

Table 9. Macroinvertabrate metrics for Pine Creek sample stations collected June-July 2003 and 2004.

	PC13		PC11		PC10	
Metric	2003	2004	2003	2004	2003	2004
No. Families	15.0	21.5	15.5	11.0	16.5	17.0
Diversity	1.95	2.81	2.37	1.68	2.34	2.62
% Tolerant	0.0	0.0	0.0	0.0	0.2	0.0
% Intolerant	10.1	31.8	15.5	14.2	15.8	24.7
% Dominant Taxa	50.7	26.3	27.4	55.5	33.0	34.04
% EPT	37.4	64.5	59.7	40.4	49.8	57.4
% Diptera	59.0	24.1	39.3	58.3	49.4	40.2
% Chironomidae	55.9	22.7	36.6	58.3	41.7	39.5

Soil Quality Response

The term soil quality, much like the term water quality, represents a suite of chemical and physical properties of soil. Within the treatment aspen stands at Pine and Bogard Creek and in adjacent control stands both before and after treatment implementation we sampled surface duff layer thickness, measured dry bulk density (g/cm^3), and collected a sample for nitrogen, phosphorus, and carbon analysis. Dry bulk density was determined via collection of intact cores (2 in diameter by 3 in depth) which were then dried in a forced air oven at 105 ^oC until a constant weight was achieved. Sample dry weight was then determined on an analytical balance accurate to 0.001 gm. Total nitrogen (N), nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), phosphate (PO_4-P), organic carbon (OC), organic matter (OM), and total carbon (C) were conducted by the University of California Division of Agriculture and Natural Resources Analytical Laboratory (DANR Lab) on the UC Davis campus following standard methods as described on their website (http://groups.ucanr.org/danranlab). Soil dry bulk density and samples for N-P-C analysis were collected at depths of 0-3 and 3-6 inches. Forty sample stations were established along permanent transects within each treatment and control stand (80 samples per stand, 40 stations at 2 depths). Soil quality and bulk density samples were collected in late June/early July of 2003 (before treatment), 2004 (1 year after treatment), and bulk density samples were collected 2005 (2 years after treatment – no soil quality samples).

Forest soils are notorious for their spatial variability, even at relatively small scales (<10 m^2). The soils at both treatment and control stands in the Pine-Bogard complex did not disappoint us. Formidable variation exists around mean calculations for almost all soil quality parameters presented in this section. Excessive variation is typically overcome with large sample size; however, with a sample size of 80 sample stations (160 samples total per year) we have pushed sample size to the practical limits of an adaptive management/monitoring project. Not to mention the fact that the field crew threatened to quit if we added more sample stations. Table 10 reports soil quality variables determined at the DANR Lab for control and treatment stands before (2003) and after (2004) conifer removal treatment. Figure 9 illustrates dry bulk density at control and treatment stands before (2003) and after (2004) conifer removal treatment. Figure 10 reports surface duff layer at control and treatment stands before (2003) and after (2004) conifer removal treatment.

We would not expect an immediate (1 year) response in soil N-P-C at either the 0-3 or 3-6 inch depth to conifer removal. Soil N, OM, OC, and C pools are quite large and thus are well buffered against short term change. Exceptions might be nitrate and phosphate, both plant and soil microbe available as well as soluble and subject to leaching. Table 10 indicates an apparent (but not significant, $P>0.05$) increase in these constituents post treatment. This apparent trend could be possible due to reduced conifer demand for these constituents. It could also be an artifact of spatial variation introducing excessive variation between years and stands. This baseline and immediate post treatment dataset provides a benchmark from which we can track changes in soil N-P-C pools as these aspen stands recover and potentially modify soil quality. We will continue to monitor these parameters on these sites in the future, but at a 3 to 5 year time step. Over time this dataset will have provide insight about nutrient cycling in aspen stands, carbon sequestration potential, and potential soil restoration targets for aspen restoration efforts.

Table 10. Mean soil quality parameters for treatment and control aspen stands in the Pine-Bogard complex before (2003) and after (2004) conifer removal in treatment stands.

		2003		2004	
Depth	Parameter	Treatment	Control	Treatment	Control
0 to 3 inch	N	0.30	0.26	0.15	0.16
	NH_4-N	10.3	10.9	9.6	8.0
	NO_3-N	0.34	0.24	0.92	0.68
	PO_4-P	24.7	29.7	20.7	13.7
	OM	9.9	8.3	6.5	6.8
	OC	5.7	4.8	3.8	4.0
	C	9.7	6.9	4.3	5.0
3 to 6 inch	N	0.13	0.13	0.10	0.11
	NH_4-N	7.4	7.5	7.4	6.7
	NO_3-N	0.23	0.13	0.61	0.51
	PO_4-P	8.8	4.4	11.1	9.1
	OM	3.9	4.2	3.9	4.4
	OC	2.2	2.5	2.3	2.6
	C	3.2	3.0	2.5	3.0

Soil bulk density is the soil quality parameter most likely to respond immediately to conifer removal treatments. Soil bulk density is a surrogate for direct measurement of soil compaction, a common impact of silvicultural practices such as skidding fallen logs to load landings. As a soil is compacted bulk density will increase. Figure 13 illustrates that bulk density in the 0 to 3 inch zone of the soil profile was significantly higher in 2004 compared to 2003. This same increase existed in 2005 (year 2 post treatment). There was no change in bulk density in the 3 to 6 inch depth zone (2003 v. 2004, or 2003 v. 2005).

The question then is if this increase in bulk density translates to a tangible effect of infiltration, overland flow and erosion potential. Given the extremely low bulk densities (<1.10 g/cm^3), it is unlikely that this level of soil compaction would reduce soil surface infiltration capacity to the point where significant runoff would occur. Figure 14 illustrates that despite the moderate compaction of the mineral soil surface layer, there was no significant reduction in the 2 to 3 inches of duff layer covering the soil surface (Photo 10). This duff layer has a major capacity to absorb and retain rainfall, as well as to provide cover to protect soil surface integrity. We are concerned that these results are reflecting inherent spatial variation in soil surface characteristics across the study stand, rather than real changes generated by the treatment. In order to address this concern, we modified the soil bulk density sample design for the McKenzie project to a “cluster” based sample collection design rather than the transect design reported here. The cluster design allows for sampling and re-sampling of a small area more precisely, reducing the potential impact of spatial variation to mask or generate differences before compared to after. Results of this approach are reported in the next section of the report (6.4).

Figure 13. Mean soil dry bulk density for treatment and control aspen stands in the Pine-Bogard complex before (2003) and after (2004) conifer removal in treatment stands.

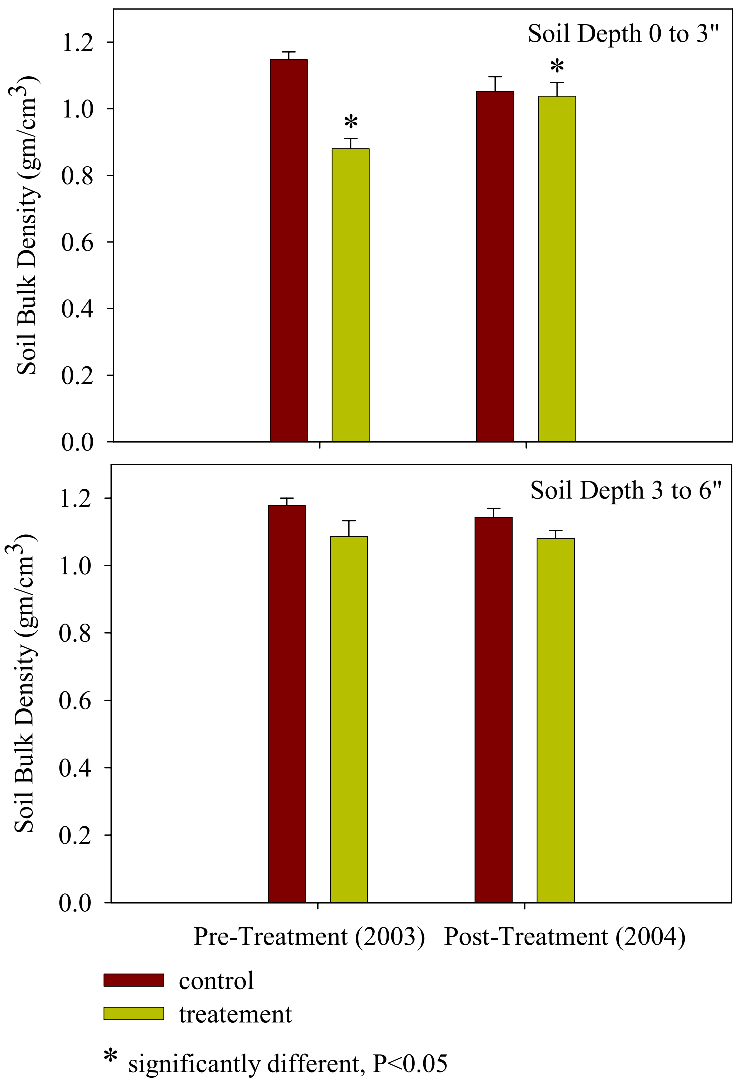


Figure 14. Mean soil surface duff layer thickness for treatment and control aspen stands in the Pine-Bogard complex before (2003) and after (2004) conifer removal in treatment stands.

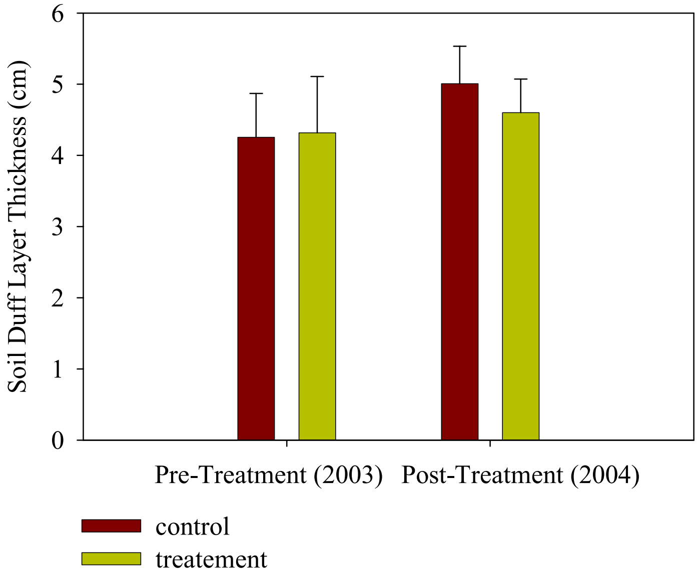


Photo 14. Soil surface duff layers average 2 to 3 inches in treatment stands following winter harvest over snow.

6.4 August 2005 McKenzie Project along Pine and Bogard Creeks

A summer conifer removal project occurred August 2005 between sites PC08 and PC11, and BO6 and BO2 on Pine and Bogard Creeks, respectively (Figure 2b "Aspen_Enhance_Summer", Photo 15). Total treatment area for this project was ~ 200 acres, with summer harvest to reduce slash, whole tree removal to reduce slash, a track-laying harvester and rubber tire skidders were used from 15 to 125 ft from stream depending upon slope and ground cover.

When combined with data collected in 2003, 2004, and 2005 prior to August 1 (before), the data collected in 2006 (1 year after) at sites PC08, PC11, BO2 and BO6 allow for analysis of before and after, above and below treatment differences for all stream related variables listed in Table 1, except macroinvertabrates. Data from other sample sites on Pine and Bogard provide insight into temporal (annual) and spatial (reach to reach) variation along these streams. Soil bulk density samples were collected before (June 2005) and 1 year after (June 2006) treatment at permanent monitoring stations (sample clusters) within the treatment stand (n=2 clusters) and within 1 control stand (n=1 cluster). Data from all years has been entered, checked for accuracy, and statistical analysis conducted. Results of this analysis are reported below for key variables of concern.

Photo 15. August 2005 McKenzie conifer removal project. Photo taken September 2005.

Stream Canopy Response

Stream canopy and solar radiation arriving at the stream surface were measured between sites PC11 and PC08 on Pine Creek and sites BO6 to BO2 on Bogard Creek using a spherical densitometer and solar pathfinder as described in section 6.3 of this report. Tree canopy cover (%) over and percent of available solar radiation reaching the stream surface (May through August) were measured along these reaches immediately before (June 2005) and after (September 2005) the August 2005 McKenzie project was

implemented. A total of 37 readings were taken between PC11 and PC08 on Pine Creek, and a total of 34 readings were taken between BO6 and BO2 on Bogard Creek before and after conifer removal. Figures 15 and 16 report mean stream canopy and solar pathfinder results before and after the August 2005 McKenzie conifer removal project adjacent to these reaches of Pine and Bogard Creeks. There were no statistically significant changes in stream canopy along treatment reaches before or after the August 2005 McKenzie project for Pine or Bogard Creeks ($P>0.33$). As a result, there were no significant changes in solar radiation arriving at the water surface along treatment reaches before or after the project for either creek ($P>0.28$). There was an apparent increase in solar input for July and August on Pine Creek, and for all months on Bogard Creek (Figure 16). The lack of significant change is not take surprising, given that the previous project on this study site (January 2004 Bogard Units Project) and the pending project (winter phase of the McKenzie project) were the projects specifically designed to reduce conifer levels within the riparian zone of this study site. Complete impacts of the McKenzie Project on stream canopy and solar input will be capable only after implementation of the winter phase of the project.

Figure 15. Mean tree canopy cover over Pine and Bogard stream reaches before and after August 2005 McKenzie conifer removal project.

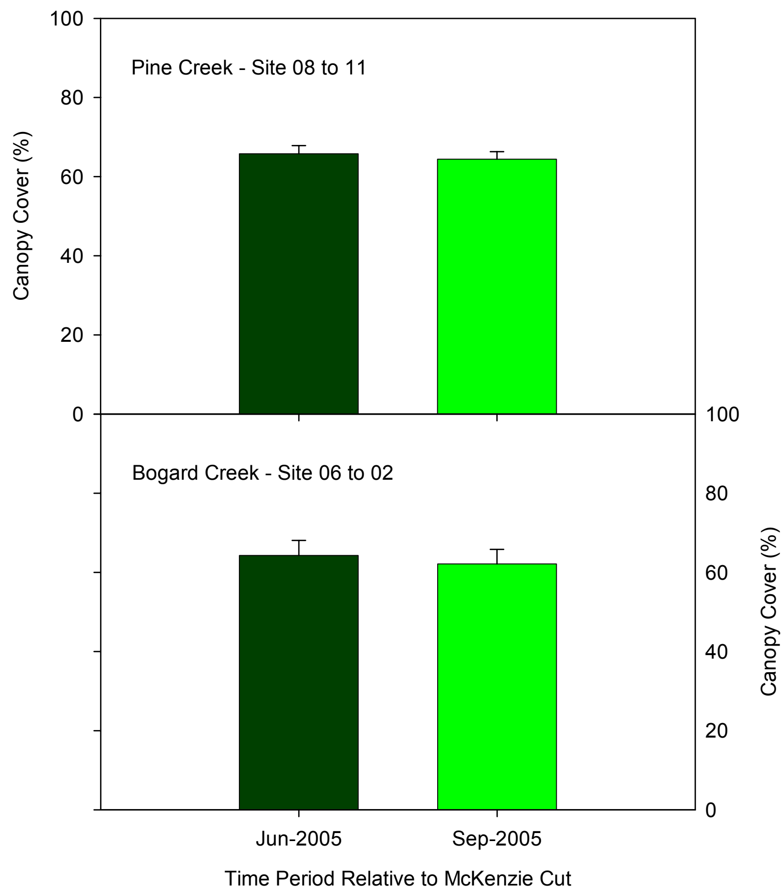
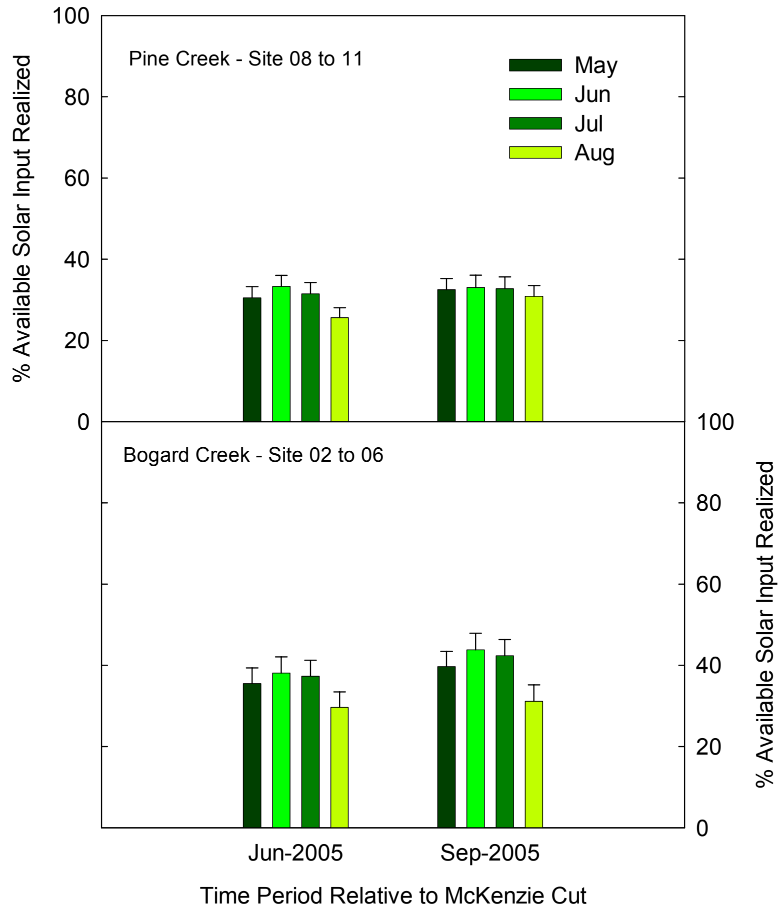


Figure 16. Mean percent of available solar radiation reaching water surface on Pine and Bogard stream reaches before and after August 2005 McKenzie conifer removal project.



Stream Temperature Response

Stream temperature data was collected at each sampling station using Onset Optic StowAway temperature dataloggers as described in section 6.3 of this report. We examined several metrics of stream water temperature above and below treatment reaches before (2003, 2004, 2005 prior to August 1) and after (2006) the August 2005 McKenzie project. Figures 17 and 18 report the 7-day running average daily maximum water temperatures observed on Pine and Bogard Creeks above and below the August 2005 McKenzie project for 2003-2006, respectively. Both reaches (Bogard BO6 to BO2, Pine PC11 to PC08 – Figure 2a and b) passing through the McKenzie project also have sub-reaches (BO6 to BO4, PC11 to PC10) which pass through the January 2004 Bogard Units project (discussed in section 6.3 of this report). Evident differences in temperature change between Figures 17 and 18 (longer McKenzie project reaches) compared to Figures 6 and 7 (shorter Bogard project reaches) are due to the effect of reaches PC10 to 08 and BO4 to BO2 on Pine and Bogard Creeks, respectively.

For the McKenzie project, years 2003 and 2004 are both before conifer removal (Figures 17 and 18). Also, the 2005 data up to ~August 1 (Julian Day = 213) is also pre treatment given that the project was not implemented until August 2005. Examining data in Figure 17 for Pine Creek from sample location PC11 (top of McKenzie project) to PC08 (bottom of McKenzie project) from May 2003 through July 2005 (before project) indicates a general pattern of increased water temperature downstream from PC11 to PC08. The rate of increase across the season (May through September) varies each year from 2003 to August 1, 2005 (Figure 17). The rate of increase was smallest during 2003, greatest during 2004, and intermediate in 2005. In all years, maximum water temperatures were optimal for cold water fisheries

(<67 F). Data reported in Figure 17 for 2006 represent the first year post August 2005 McKenzie project, and also represent the coldest water temperatures of the 4 year period. The general pattern of increased water temperature from PC11 downstream to PC08 is evident, but the rate of increase is not significantly different from that realized in 2004 or 2005 ($P>0.38$), both pre treatment years. The rates of increase observed in 2004, 2005, and 2006 were all significantly greater that 2003 ($P>0.05$). These results indicate that there was no significant impact of the August 2005 McKenzie project on maximum stream temperatures for the associated reach of Pine Creek. Given that the project did not impact stream canopy or solar input to this reach, it is not surprising that there was no impact on water temperature.

Figure 18 reports maximum stream temperatures for the section of Bogard Creek (BO6 to BO2) associated with the August 2005 McKenzie project. As discussed in the previous paragraph, 2003-August 1, 2005 represent pre treatment conditions, and 2006 represents post treatment conditions. Two patterns of change are evident in this data. During 2003 and 2005, there is an increase in temperature downstream from BO6 to BO2 from about May 15 through August 1. However, for the remainder of each year (August 1 through September 30), water temperature actually cools as it passes downstream from BO6 to BO2. The temperature patterns for 2003 and 2005 are not significantly different from each other ($P=0.54$). The second pattern evident in this dataset occurs during 2004 and 2006. During these years the water temperature increases from BO6 to BO2 for the entire season, and the rate of increase between these years are not significantly different from each other ($P=0.21$), although there is an apparently greater rate of increase in 2004 (pre treatment). Patterns for 2003 and 2005 are significantly different from 2004 and 2006 ($P<0.05$). For all years and all sites, maximum water temperatures are within optimal conditions for cold water fisheries (<67 F). As with Pine Creek, 2006 is the coldest year in the dataset. These results indicate that there was no significant impact of the August 2005 McKenzie project on maximum stream temperatures for the associated reach of Bogard Creek. As with Pine Creek, given that the project did not impact stream canopy or solar input to this reach, it is not surprising that there was no impact on water temperature.

The two distinct patterns of temperature change (late season cooling v. heating) from BO6 downstream to BO2 are very likely due to annual streamflow conditions. In particular how the stream's surface flow is interacting with cooler sub-surface riparian flows. Over the course of summer baseflow, stream reaches can gain water from sub-surface riparian sources, lose water to sub-surface riparian sinks, and/or have no net gain or loss to riparian sub-surface sources/sinks. Alluvial-meadow stream reaches tend to have more interactions (gain/loss) with subsurface water sources/sinks than bedrock-forest reaches. The lower reach of Bogard (BO3 to BO2) is an alluvial-meadow reach. Figure 19 reports change in streamflow (cubic feet per second) from BO6 to BO2 for all sample dates during 2003 through 2006. During 2003 and 2005 (cooling years), the gain in streamflow increased over the season (particularly during August), while gain in streamflow decreased throughout the season for 2004 and 2006 (heating years). Although not a direct test, these data indicate that late season flows arriving at BO2 in 2003 and 2005 were composed of a greater percentage of sub-surface return flow than were late season flows in 2004 and 2006. Sub-surface return flow tends to be cooler than surface flows in hot, arid regions during late summer season, and could account for the two different patterns of temperature change through this reach of Bogard Creek for different years. We have documented similar patterns of temperature gain and loss in the Warner Mountains in northeastern CA (Tate et al. 2005, http://californiaagriculture.ucop.edu/0503JAS/toc.html). It is also possible that annual variation in air temperature could impact stream temperature changes, but examination of air temperatures during the study period do not reveal patterns that would indicate this to be the case (Figure 20).

Figure 17. Maximum stream temperature observed above (PC11) and below (PC08) August 2005 McKenzie conifer removal project on Pine Creek.

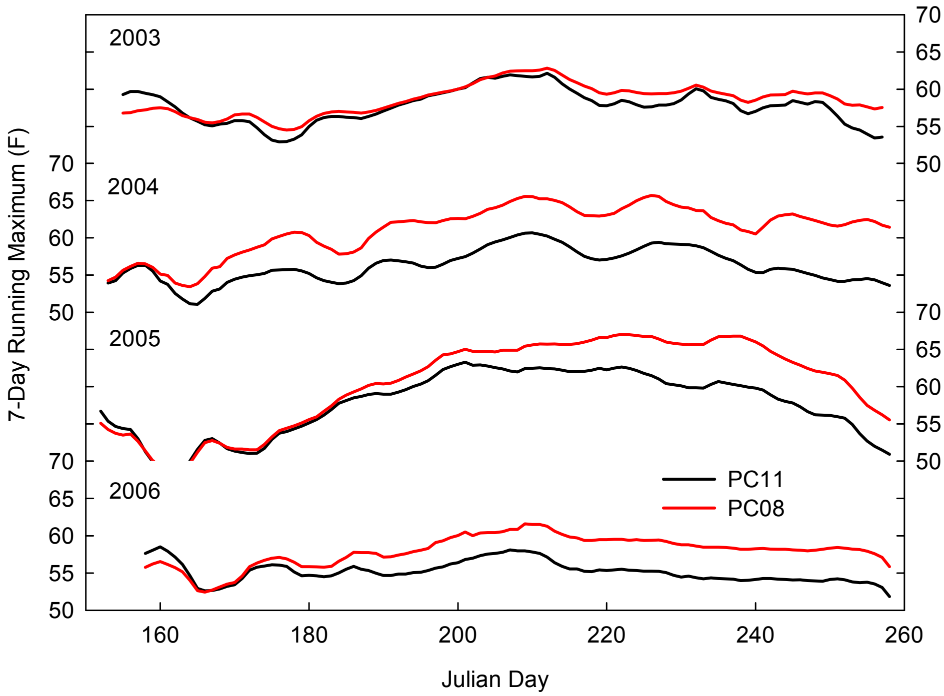


Figure 18. Maximum stream temperature observed above (BO6) and below (BO2) August 2005 McKenzie conifer removal project on Bogard Creek.

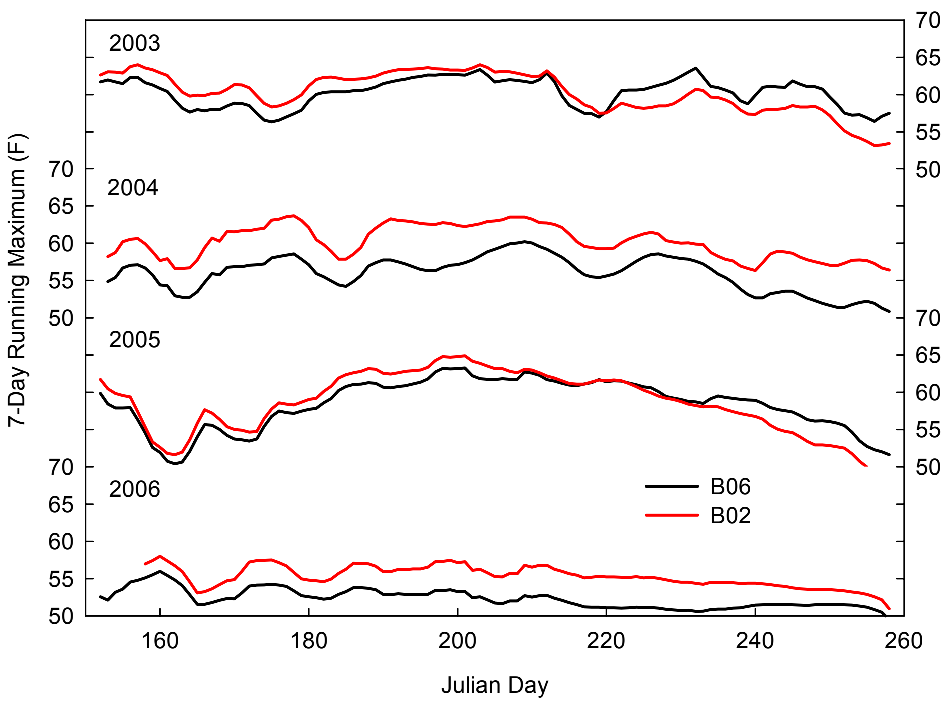


Figure 19. Change in streamflow (cubic feet per second) downstream from sample station BO6 to BO2 on Bogard Creek May through September 2003 through 2006.

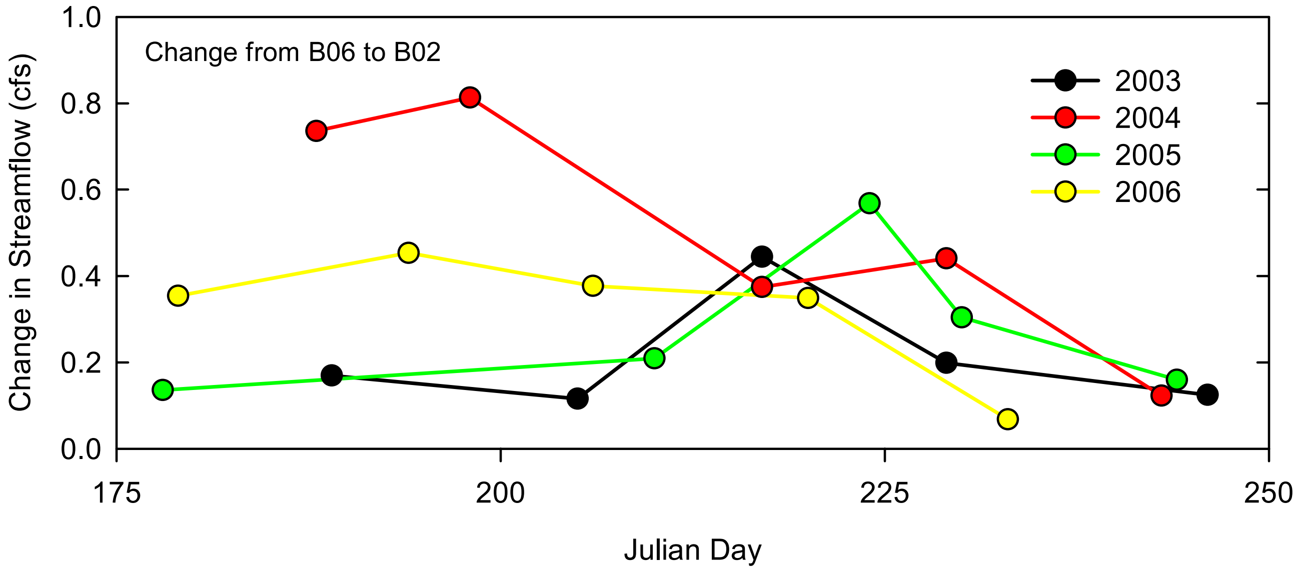
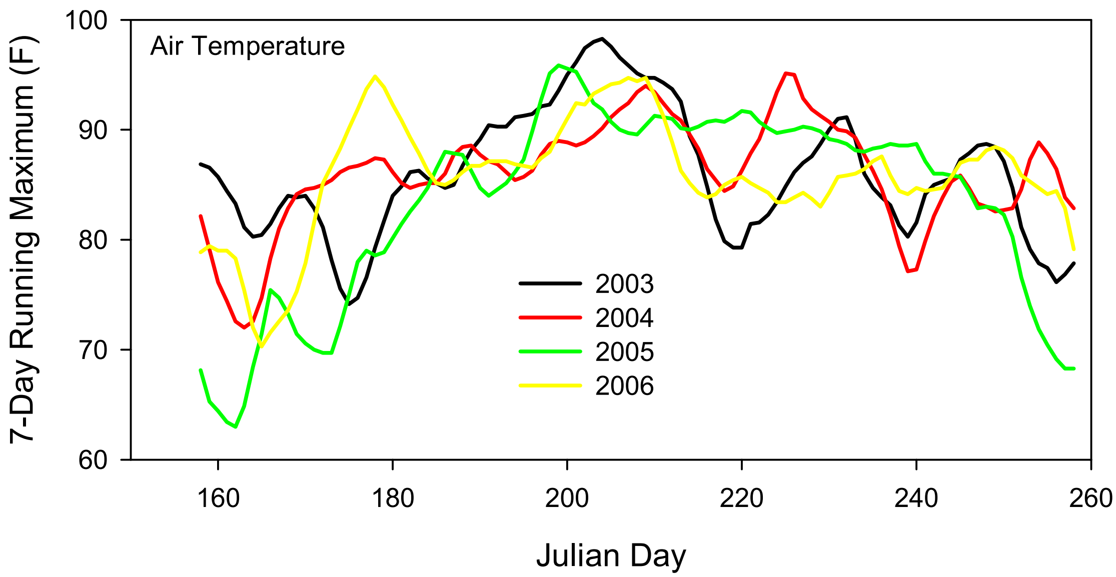


Figure 20. Daily air temperature observed at Pine and Bogard Creeks May through September 2003 through 2006.



Stream Chemistry and Sediments

Stream water samples were grab sampled every 2 weeks from ~May 15 to ~September 30 from 2003 through 2006 as described in section 6.3 of this report. Stream chemistry analysis for all sites associated with the August 2005 McKenzie project (PC11, PC10, PC09, PC08, BO6, BO5, BO4, BO3, and BO2) for all years revealed extremely clean water conditions. Nitrate and ammonium concentrations (2003 through 2006) on all Pine and Bogard Creek sites were below our detection limit (0.01 mg/L or ppm) for over 75% of samples collected, making statistical analysis unfeasible and unnecessary. Over 75% of Pine Creek phosphate concentrations were <0.01 mg/L. Approximately 20% of all Bogard Creek samples were <0.01 mg/L for phosphate. Phosphate levels are inherently higher on Bogard Creek (we can actually

detect it 80% of the time) compared to Pine Creek due to the large influence of Bogard Springs sub-surface flow (phosphorus is derived from geologic weathering and related sources) on Bogard Creek's background chemistry. There is no evidence that the chemistry of either Pine or Bogard Creeks have been impacted by the McKenzie project. Table 6 provides a representative look at the concentrations and levels of the various constituents examined.

Figures 9 through 12 report suspended sediment concentrations and turbidity levels for all sample sites on Pine and Bogard Creeks from 2003 through 2006, and allow comparison of before (2003-August 1, 2005) v. after (2006), above (PC11, BO6) and below (PC08, BO2) the August 2005 McKenzie project. As discussed in section 6.3, these figures also allow examination of spatial and temporal patterns along the entire length of Pine and Bogard Creeks both before and after the project.

Figures 9 and 10 show that 2006 (after August 2005 McKenzie project) had the lowest sediment and turbidity levels of all 4 years (2003 through 2006) on Bogard Creek. Levels for both sediment and turbidity were significantly lower in 2005 and 2006 compared to 2003 and 2004 at all sites ($P<0.05$). The highest average levels were recorded in 2004 ($P<0.05$). As examination of data for Figures 9 and 10 indicates, 2004 was the only year with a significant change (decrease) in sediment and turbidity from site BO6 to BO2. The change between sites in all other years was not significant ($P>0.56$). These results indicate that there was no increase in sediment or turbidity in Bogard Creek as a result of the August 2005 McKenzie project.

Figures 11 and 12 show that 2006 (after August 2005 McKenzie project) had the lowest sediment and turbidity levels of all 4 years (2003 through 2006) on Pine Creek. Levels for both sediment and turbidity were significantly lower in 2005 and 2006 compared to 2003 and 2004 at most sites ($P<0.05$). The highest average levels were recorded in 2004 ($P<0.05$). Comparison of sample location PC11 to PC08 for 2003 through August 1, 2005 to 2006 indicate no clear pattern of increased sediment or turbidity levels following the August 2005 McKenzie project. Both sediment and turbidity levels increased consistently from PC11 to PC08 during 2004 through 2006. In 2003, both sediment and turbidity levels decreased from PC11 to PC08 in a manner statistically different from 2004 through 2006 ($P<0.05$). However, the timing of this pattern does not match the timing of the August 2005 McKenzie project, and cannot be attributed to the January 2004 Bogard Unit project which occurred completely upstream of PC10 (i.e. does not explain the increases observed at sites PC09 and PC08). It is also important to reiterate the exceptionally low levels of sediment and turbidity observed in both Pine and Bogard Creeks over the study period, as discussed in section 6.3 of this report.

Soil Bulk Density Response

Soil bulk density samples were collected June 2005 (before August 2005 McKenzie project) and June 2006 (after) at 3 monitoring stations (sample clusters). Two of the monitoring stations were within the project area (treatment) and one was outside the project area (control). Samples were collected via core method at depths of 0 to 6 and 6 to 12 inches. Twenty-five samples were collected at each monitoring station on each sample date. Samples were dried and dry bulk density determined as gm/cm^3. As with all statistical analysis reported to date, linear mixed effects analysis was used to specifically test if there was a significant change in bulk density in treatment stations after treatment relative to control stations.

Figure 21 reports mean bulk density for treatment (harvested) and control (no harvest) monitoring stations before (2005) and after (2006) the August 2005 McKenzie project at both soil depths (0-6 and 6-12 inches). There was no significant change in soil bulk density of treatment stations relative to control stations at depth 0-6 in ($P=0.88$) or 6-12 in ($P=0.22$) after implementation of the project. These results indicate that there was no soil compaction at these sites, which represent harvest unit areas outside of

defined skid trails and log landings. We found the monitoring station (cluster sample scheme) approach reported here to be a great improvement over the sample transect approach previously used for the January 2004 Bogard Units project (section 6.3). The monitoring station approach allows for much greater spatial repeatability of sample collection compared to the transect method, allowing for control of spatial variation inherent across these forest soils.

Figure 21. Soil bulk density at treatment and control monitoring stations before and after the August 2005 McKenzie project.